CHAPTER 2 -- DESCRIPTION OF THE WATER BODY

INTRODUCTION

The Loxahatchee River and Estuary and its upstream watershed are located along the southeastern coast of Florida within the Lower East Coast Planning area (SFWMD, 2000a). This watershed drains an area of approximately 210 square miles, is located within northern Palm Beach and southern Martin Counties, and connects to the Atlantic Ocean via the Jupiter Inlet, near Jupiter, Florida. The Loxahatchee Estuary central embayment is located at the confluence of three major tributaries -- the Northwest Fork, the North Fork and the Southwest Fork. The Northwest Fork originates at the G-92 Structure in northern Palm Beach County, flows north, enters Martin County, continues north and bends east through Jonathan Dickinson State Park (JDSP), and then flows southeast through the central embayment **(Figure 2**). The Atlantic Coastal Ridge in Eastern Martin County defines the headwaters of the North Fork, which flows south-southeast into the central embayment. All but one mile of the Southwest Fork has been channelized to form the C-18 Canal (C-18), which flows northeast through Palm Beach County to discharge into the central embayment. The central embayment connects to the Atlantic Ocean through Jupiter Inlet.

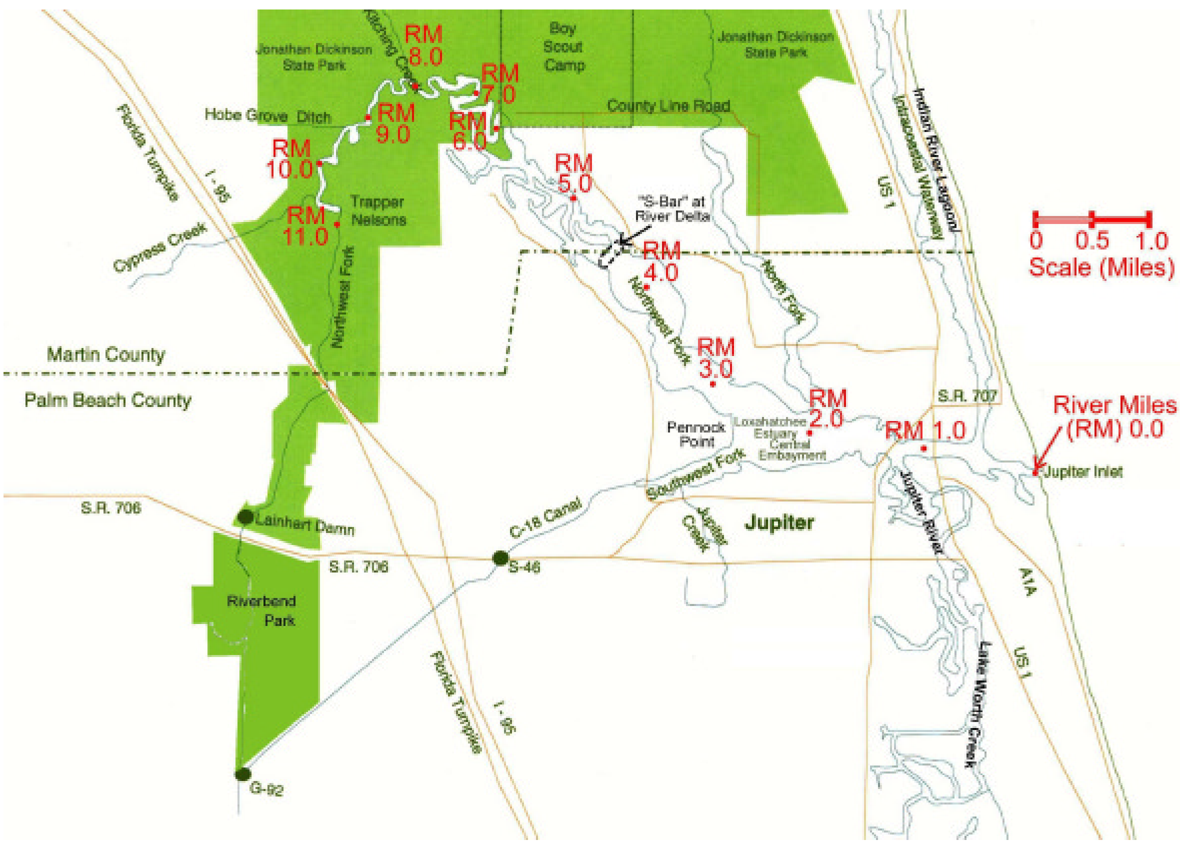


Figure 2. Locations of Major Features in the Loxahatchee River and Estuary. (RM = river miles upstream from Jupiter Inlet)

The Loxahatchee River and upstream floodplain are unique regional resources in several ways. The river has often been referred to as the "last free flowing river in southeast Florida". In May 1985, a 7.5 mile reach of the Northwest Fork of the Loxahatchee River was federally designated as Florida's first Wild and Scenic River. In addition, different portions of the river and estuary are designated as an aquatic preserve, Outstanding Florida Waters and a state park. The Northwest Fork represents one of the last vestiges of native cypress river-swamp within southeast Florida. Large sections of the river's watershed and river corridor are included within JDSP, which contains outstanding examples of the region's natural habitats.

The watershed is unique in that it contains a number of natural areas that are essentially intact and in public ownership. These areas include the J.W. Corbett Wildlife Management Area, JDSP, Hungryland Slough Natural Area, Loxahatchee Slough Natural Area, Hobe Sound National Wildlife Refuge, Juno Hills Natural Area, Jupiter Ridge Natural Area, Pal-Mar, Cypress Creek and the Atlantic Coastal Ridge. These natural areas contain pinelands, sand pine scrub, xeric oak scrub, hardwood hammock, freshwater marsh, wet prairie, cypress swamp, mangrove swamps, ponds, sloughs, river and streams, seagrass and oyster beds and coastal dunes. These areas support diverse biological communities, including many protected species (FDEP, 1998).

Preservation and enhancement of the outstanding natural and cultural values are the primary goals of the SFWMD's management program for this unique, "wild and scenic river" this area. The SFWMD vision for protecting the water resources of the river include: 1) maintaining surface water and ground water flows to the Northwest Fork; 2) providing minimum flows to control upstream movement of the saltwater wedge during dry conditions; 3) maintaining existing water quality in the river by eliminating identified water quality problems; 4) providing freshwater flows needed to sustain natural systems within the downstream river and estuary. In addition, The SFWMD and FDEP jointly developed a *Proposed Restoration Vision for the Northwest Fork of the Loxahatchee River* in September 2001 and are presently working with other agencies, local interests and concerned citizens to develop a practical restoration plan for this river.

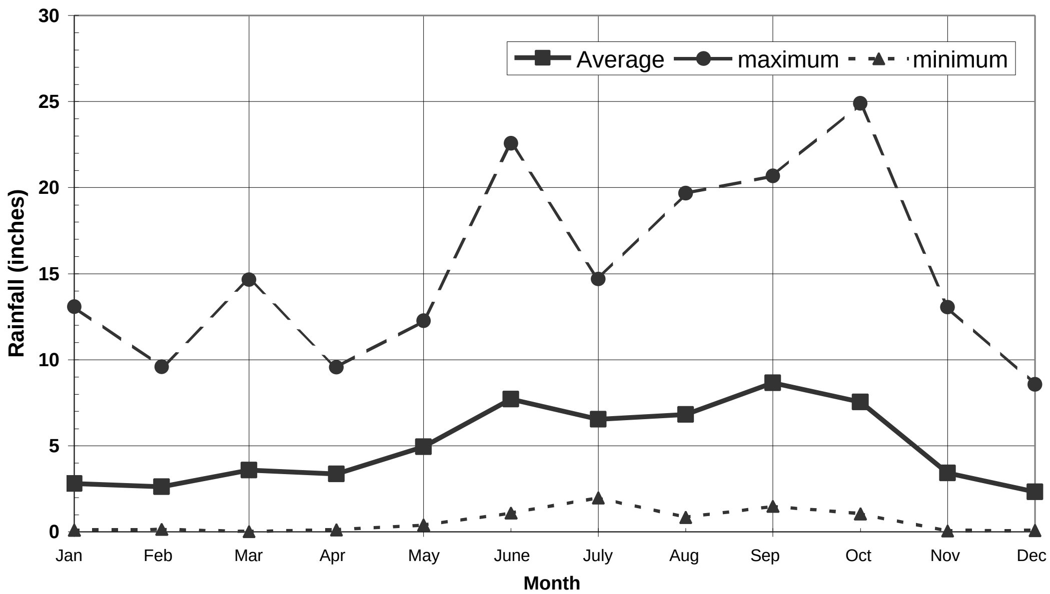
DESCRIPTION OF THE WATERSHED

Climate, Rainfall and Seasonal Weather Patterns

The climate is subtropical with daily temperatures ranging from an average of 82^{o} F in summer to an average of 66^{o} F in winter. Winters are mild with warm days and moderately cool nights. August is the warmest month, usually having more than 29 days with temperatures above 90 ^{o} F. Even in the coldest winters, temperatures at or below freezing are rare. The average annual temperature is 75^{o} F (Breedlove, 1982).

Prevailing winds are east/southeast, providing a marine influence, with an average velocity of approximately 10 miles per hour. Air in the study area is moist and unstable. These characteristics lead to frequent rain showers, usually of short duration. During the summer months, thundershowers occur on average, every other day.

Rainfall within the Loxahatchee River watershed averages about 61 inches annually (Breedlove, 1982; Dent 1997a) with a median value of about 57 inches. Heaviest precipitation occurs during the wet season. Dent (1997a) reports that since the early 1960s, about two-thirds of this precipitation (40.63 inches) occurs during the wet season (May through October), while the remaining one-third (20.42 inches) falls during the dry season (November–April). These data agree with rainfall data generated from the South Florida Water Management Model (SFWMM) (SFWMD 1998) for a longer period of record (1914–2000) for northern Palm Beach and southern Martin Counties **(Figure 3).**

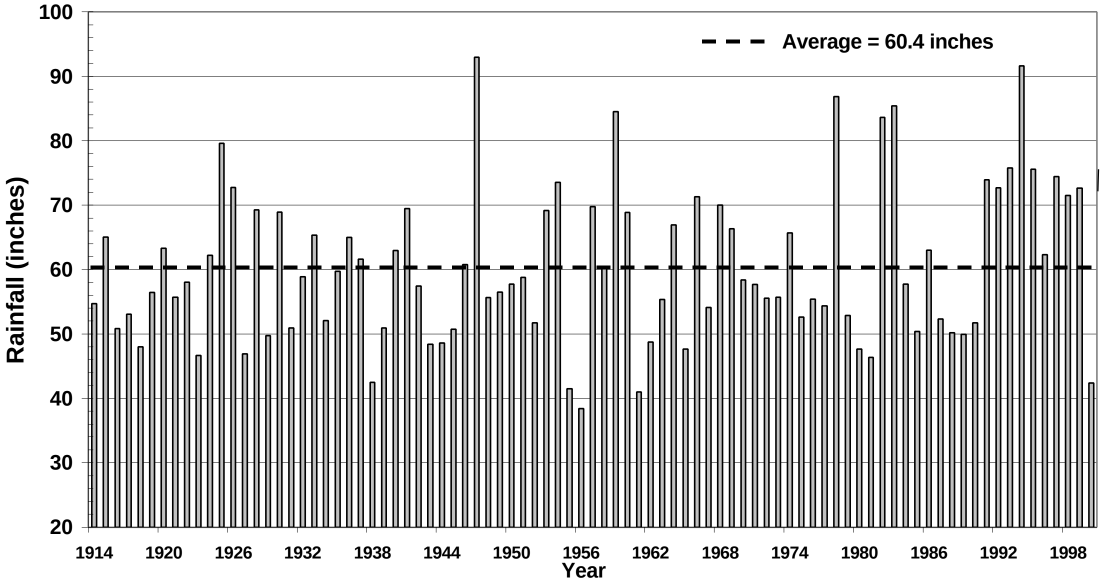


Source: Model results from the South Florida Water Mangement Model (SFWMM)

Figure 3. Average, Minimum and Maximum Rainfall Values, by Month, for Northern Palm Beach and Southern Martin Counties (1914–2000)

On average, the highest rainfall of 8.7 inches per month occurs during the month of September, while minimum average values range from 2.3–2.8 inches/month for the months of December, January and February **(Figure 3)**. May and November are transitional months and sometimes represent key months for either prolonging or relieving a drought or flood condition (Dent, 1997a). During the winter and early spring, some years have long periods of little or no rainfall, resulting in a regional drought condition. In contrast, tropical storms or hurricanes over the area can produce as much as 6 to 10 inches of rainfall in one day. Total annual rainfall can be as much as 93 inches or as low as 38 inches (**Figure 4).**

Figure 4 provides a summary of annual rainfall amounts received within northern Palm Beach and southern Martin Counties from 1914–2000 (data from South Florida Water Management Model, version 9.7). Mean annual rainfall for the full 86 year period of record was 60.4 inches with a median of 57.7 inches. The maximum amounts of rainfall recorded were 92.9 (1947) and 91.6 inches (1994). Minimum rainfall values occurred in 1956 (38.4 inches) and 1961 (41 inches). Review of the distribution of annual rainfall data over time showed that a variance of about 10 percent of the mean (plus or minus 6 inches) occurs about once every three years on average. Extreme dry and wet periods can be defined as a variance of more than 20 percent of the mean (± 12 inches). Based on this definition, the long-term record shows that an extreme dry period occurs within the basin about once every 8.6 years, while extreme wet periods occur about once every 5.7 years.



Source: South Florida Water Mangement Model

Data obtained from the following grid cells representing northern Palm Beach and southern Martin counities: Row 65 columns 32-38, Row 64 columns 30-38, Row 63 columns 30-38, Row 62 columns 30-38, Row 61 columns 30-37, Row 60 columns 31-37, Row 59 columns 32-37, Row 58 columns 33-

Figure 4. Long-term Annual Rainfall for Northern Palm Beach and Southern Martin Counties (1914–2000)

Comparison of the rainfall data contained in **Figure 4** to the period of time (1971–2001) that we have known flow records for the Northwest Fork of the Loxahatchee River shows that the 1970s and 1980s were a relatively dry period compared to the 1990s. For example, annual rainfall amounts exceeded more than 12 inches of the mean seven out of 10 years from 1990–2000 (**Figure 4**). These large rainfall differences between the 1970s and 1980s and the 1990s are thought to be an important factor that needs to be considered in reviewing past impacts to the river and its flora and fauna. These relationships are explained in detail later in this report.

Dent (1997a) provides information about the spatial distribution of rainfall across the Loxahatchee River watershed. Unpublished data and the results of modeling work on the Loxahatchee slough both indicate that wet season rainfall is higher inland as compared to rainfall stations located nearer the coast. Wet season rainfall recorded at the Jonathan's Landing development located near the coast was 12 percent less than observed at the more centrally located Loxahatchee River District site, and 34 percent lower than the western Pratt & Whitney site. Summer wet season rainfall data collected at the Loxahatchee River District monitoring site (located near the I-95 corridor) was 25 percent lower than experienced at the western edge of the watershed (Dent, 1997a). These results are similar to MacVicar (1981) who reported that the predominance of convective type rainfall in South Florida during the wet season results in much higher rainfall totals on the mainland than along the shore or coastal islands.

Evapotranspiration (ET) is the sum of evaporation and transpiration. Like rainfall, ET is generally expressed in terms of inches of water per year. For the South Florida area, ET returns approximately 45 inches of water per year to the atmosphere. The excess of average precipitation over average ET (15 inches) is equal to the combined amounts of average surface water runoff and average ground water recharge.

Pre-Development Hydrology

The Loxahatchee River historically received flow into the Northwest Fork from the Loxahatchee Marsh (Slough) and the Hungryland Slough (see **Figure 5**). Both of these wetland areas drained to the north from the low divides near State Road (SR) 710 (Parker et al., 1955). Historically, this area was characterized by swampy flatlands interspersed with small, often interconnected ponds and streams that produced sheet flow that might be directed north or south, depending on local conditions. Drainage patterns were determined by the poorly defined natural landforms of the area.

The major features that presently influence drainage in the river basin are the C-18 canal, the Florida Turnpike, Interstate 95 (I-95), Beeline Highway (SR 710) and Bridge Road (SR 708), which act as important subbasin divides, and the extensive system of secondary canals developed by special drainage districts and landowners within the basin. Since the turn of the century, human activities have altered almost all of the natural drainage patterns within the basin. Many areas that once were wetlands, ponds and sloughs, are now a network of drainage canals, ditches, roads, super-highways, well-drained farms, citrus groves, golf courses and residential developments. The drainage network has lowered ground water levels and significantly altered surface water flows to the estuary (McPherson and Sabanskas 1980). In 1957–1958, the C-18 Canal was constructed through the central portion of the Loxahatchee Slough (the headwaters of the Loxahatchee River) for flood protection purposes. This project redirected flows from the Northwest Fork to the Southwest Fork from the early 1960s up to 1974, when the G-92 structure was constructed to reconnect the C-18 and Loxahatchee Slough with the Northwest Fork.

Coastal development has also greatly affected the hydrology of the Loxahatchee River Estuary. The natural mouth of the estuary, the Jupiter Inlet, opened and closed many times as the result of natural conditions. Originally the inlet remained open due to flows from the Loxahatchee River, Jupiter Sound, Jupiter River and Lake Worth Creek. Near the turn of the century, some of this flow was diverted by the construction of the Intracoastal Waterway (ICW) and the Lake Worth Inlet, and modification of the St. Lucie Inlet. Subsequently the Jupiter Inlet remained closed much of the time (except when it was periodically dredged) until 1947 when it became permanently opened by the United States Army Corps of Engineers (USACE) (McPherson and Sabanskas, 1980).

Major Drainage Sub-Basins

The major feature of the watershed is the Loxahatchee River, which historically drained 270 square miles of inland sloughs and wetlands. Some of the major tributary streams, such as the North Fork, the Northwest Fork and Kitching Creek exist today largely within their historic banks. Other creeks, such as the Southwest Fork, Limestone Creek and parts of Cypress Creek, have been greatly altered. Today the watershed encompasses about 80 percent of its historic size (about 210 sq. miles). More than half of the land still remains undeveloped and the remainder has been altered by agricultural or urban development. Undeveloped lands consist of wetlands and uplands. The watershed also contains about 4000 acres of open water including lakes and the estuary (FDEP, 1998).

Although the total area of the watershed has not changed dramatically, drainage patterns have been significantly altered due to road construction (e.g., S.R. 710, I-95, and Florida Turnpike), construction of the C-18 and associated water control structures, and development of an extensive secondary canal network. The canals were designed primarily to provide drainage and flood protection for agricultural and urban development and associated water conveyance for potable use and irrigation. Drainage and development have lowered ground water levels and altered natural flow regimes and drainage patterns.

The watershed contains seven drainage subbasins, varying in size from 17 to 100 square miles, which provide runoff to the three forks of the Loxahatchee River (**Figure 5**). The subbasin boundaries were based primarily on hydrology and secondarily on land use. Each of these subbasins plays an important role in the watershed.

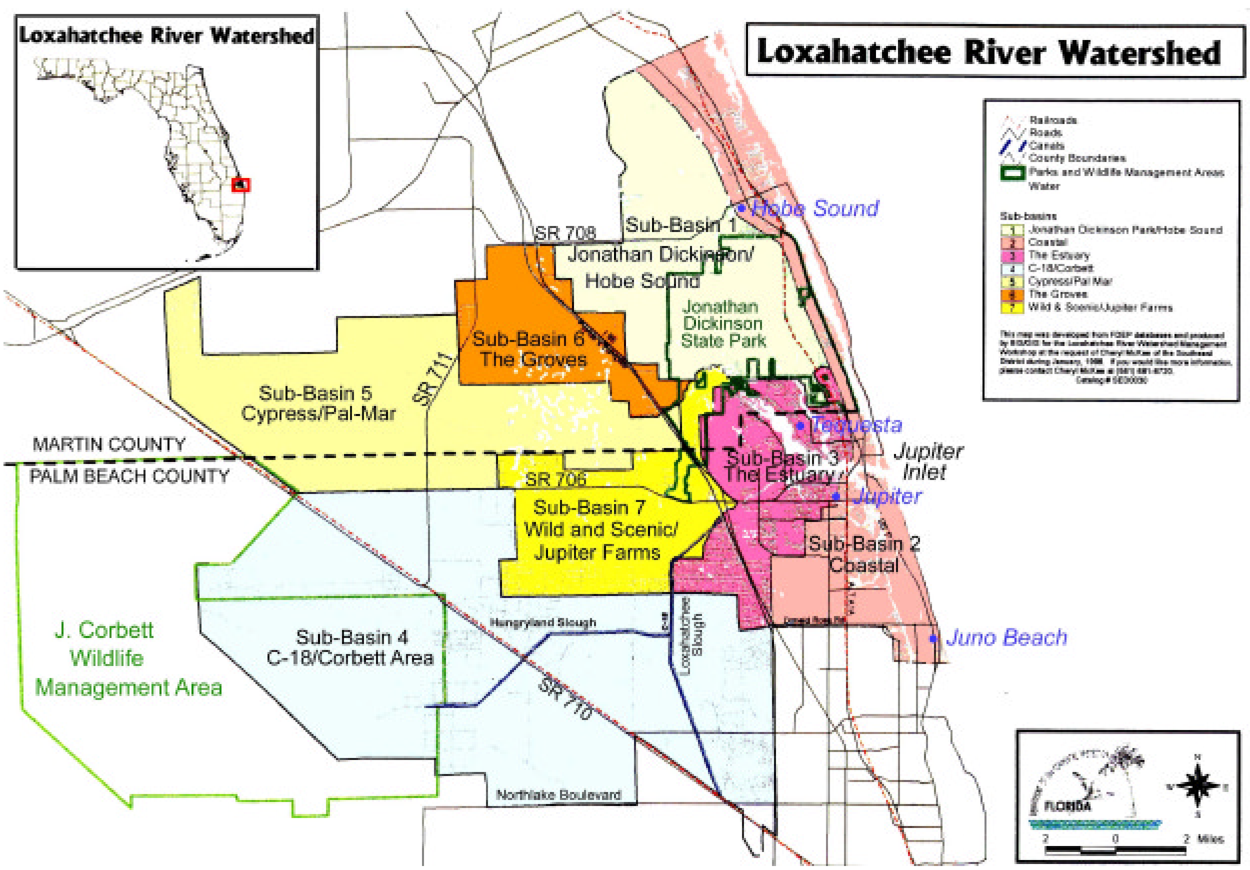


Figure 5. Major Drainage Basins in the Loxahatchee River Watershed (source: FDEP, 1998)

Subbasin 1: Jonathan Dickinson. The northeastern portion of the Loxahatchee River watershed actually consists of two parallel basins, the North Fork of the Loxahatchee and Kitching Creek. Over 40 percent of the 36 square miles of this subbasin are within the boundaries of JDSP, and contribute runoff from natural lands. A portion of surface and ground waters from this basin flows into the North Fork River. The remainder flows into Kitching Creek and discharges into the Northwest Fork near river mile 8.2.

Subbasin 2: Coastal. This subbasin consists of approximately 34 square miles of land that drains to the ICW and out the Jupiter Inlet. The coastal subbasin has been developed for maximum urban residential, commercial and recreational use. Very few small and isolated natural areas remain. Most of the surface water and ground water from this sub-basin discharges to marine waters rather than towards to the freshwater portion of the Northwest Fork.

Subbasin 3: Estuary. This central drainage subbasin is highly developed with urban land uses and contributes significant runoff to the major embayment of the Loxahatchee River. Consisting of over 21 square miles of the watershed, this subbasin provides aquatic recreational opportunities that sometimes exceed the river's carrying capacity on weekends and holidays. Runoff and groundwater from most of this sub-basin discharge to brackish waters of the estuary.

Subbasin 4: C-18/Corbett Wildlife Management Area (WMA). Over 100 square miles make this the largest subbasin in the watershed. Much of the land in this subbasin, comprising the southwestern portion of the watershed, is publicly owned and protected. This subbasin includes the remnants of the Hungryland and Loxahatchee Sloughs, which historically fed the Northwest Fork of the Loxahatchee River. At one time, the Loxahatchee Slough extended south into what is now known as the Grassy Waters Preserve (West Palm Beach Water Catchment Area), which is the source of drinking water for the City of West Palm Beach. Water from this sub-basin discharges to C-18 Canal, and is discharged to either the Southwest Fork or through the G-92 structure to the upper end of Northwest Fork of the Loxahatchee River

Subbasin 5: Cypress Creek/Pal-Mar. Cypress Creek, a large 46 square mile subbasin, drains a sizable wetland located in the western extremities of the watershed and is one of the major tributaries to the Loxahatchee River. Most of these wetlands remain intact, however the eastern flow ways leading to the creek have been disturbed by rural development. Water from this sub-basin flows into Cypress Creek and discharges at the upper end of the Northwest Fork near river mile 10

Subbasin 6: Groves. While agricultural operations are found in four of the seven subbasins, the predominant land use in this 17 square mile subbasin is primarily citrus. Although the hydrology in this subbasin has been altered to support agriculture, wildlife utilization is good and the land provides a valuable greenway link between large natural areas within the watershed. Water from this sub-basin flows into Hobe Groves Ditch and discharges into the Northwest Fork near river mile 9

Subbasin 7: Wild and Scenic River/Jupiter Farms. This subbasin is over 23 square miles and is divided into a larger upstream section, which has been channelized and now supports substantial rural development (Jupiter Farms), and the downstream portion that comprises the “wild and scenic” Northwest Fork of the Loxahatchee River. Water quality in the Northwest Fork is a concern in this subbasin (FDEP, 1998). Water from the upstream section of this sub-basin discharges into the upper end of the Loxahatchee River between the G-2 structure and Lainhart Dam. The downstream section of this sub-basin discharges directly into the Northwest Fork.

WATERSHED COMPONENTS

The Loxahatchee River and Estuary system can be divided into three components that affect, or are affected by the need to establish minimum flows and levels (MFLs). These include:

- The Northwest Fork of the Loxahatchee River (especially the “wild and scenic river” corridor) and its upstream watershed which includes the Loxahatchee Slough, JDSP, Cypress Creek, Hobe Grove Ditch and Kitching Creek.
- Downstream areas include the Northwest Fork Estuary, Southwest Fork, North Fork, and the central embayment.
- Adjacent coastal waters of the ICW, Jupiter River and Jupiter Inlet.

Northwest Fork of the Loxahatchee River and Upstream Watershed

Physical Features

The Northwest Fork of the Loxahatchee River originates in the Loxahatchee Slough. The slough receives discharges from C-18 Canal and runoff and groundwater inflow from adjacent uplands. Downstream from the slough, the Northwest Fork receives additional input from three major tributaries -- **Cypress Creek,** which drains Ranch Colony, Pal Mar and a portion of the Groves subbasin; **Hobe Grove Ditch**, which drains a portion the Groves subbasin, and **Kitching Creek,** which drains wetlands north of the river **(Figure 2).** The Northwest Fork passes through cypress swamp, mangrove forest, historical and archeological sites, and JDSP to the saline waters of the estuary. The Northwest Fork is a natural river channel. Average depths generally range from 3 to 6 feet deep (Chiu, 1975). Maximum depths range from 10 to 16 feet upstream near Cypress Creek. Farther upstream, maximum depths are generally less than 10 feet. Much of the watershed remains in a natural (undeveloped) state or in low-intensity agricultural use so that the quality of runoff water from most areas is good. Large tracts are protected in parks or preserves, and additional land is being purchased by various private interests and government entities for preservation.

Floodplain Plant Communities

The floodplain of the Northwest Fork of the river is a prime example of a pristine subtropical riverine cypress swamp and represents a last vestige of this community within southeast Florida (USDOI and NPS, 1982). The cypress swamp community extends 4 miles down the Northwest Fork from Indiantown Road. Originally the cypress forest extended further downstream to near river mile 5.5 (McPherson unpublished data). Today, freshwater cypress and hardwood communities share the floodplain with saltwater tolerant mangroves from river mile 8.6 to river mile 10 (see **Appendix B** and **Appendix C**) as a result of saltwater intrusion. The remaining cypress swamp community along this stretch of the river exhibits high species diversity due to the overlap of tropical and temperate zone communities. Tropical vegetation, such as wild coffee, myrsine, leather fern, and cocoplum may be found along with pop ash, water hickory, red bay, royal fern and buttonbush, which are considered to be more northern flora (USDOI and NPS, 1982). The slightly elevated areas that border the Northwest Fork of the river are dominated by slash pine and saw palmetto. Also common are areas of dwarfed and gnarled scrub oak and many herbs and grasses. Threats to floodplain vegetation include periods of saltwater intrusion within upstream areas of the river, which result in death or stress to the remaining freshwater species, replacement by salt tolerant species, such as red mangroves and replacement by exotic species such as Brazilian pepper and climbing ferns.

Existing historical aerial photographs were used to compare spatial and temporal changes in the distribution and abundance of vegetation communities along the floodplain of the Northwest Fork of the Loxahatchee River, document changes in vegetation cover, and correlate those changes to major events in the watershed. A detailed description of the methods and results of this study are available in **Appendix B**.

1940 Vegetation Communities

Figure B-2, **Appendix B** shows the distribution of major vegetation communities found along the Northwest Fork and adjacent areas (including the floodplain, wetlands in JDSP and some uplands) in 1940, based on a review of historical black and white aerial photographs. **Table 1** summarizes the coverage (in acres) and changes in coverage of each community type for 1940, 1985 and 1995.

Table 1. Interpreted Vegetation Coverages (acres) for 1940, 1985 and 1995 for the Northwest Fork and Adjacent Areas, from River Miles 4.5 to 11.2, Based on Aerial Photography.

VEGETATION	1940 Coverage	1985 Coverage	1995 Coverage	Acres Difference 1940-1985	Acres Difference 1940-1995	Acres Difference 1985-1995
Freshwater Plant Communities						
Swamp Hardwood Cypress Stream Swamp**	467	338	326	-129	-141	-12
Inland Ponds and Sloughs	59	39	39	-20	-20	0
Freshwater Marsh	NA	5	2	NA	NA	-3
Cabbage Palm	3	7	4	+4	+1	-3
Category Total	***529***	***389***	***371***	***-145***	***-160***	***-18***
Saltwater Tolerant Plant Communities						
Mangrove	163	161	152	-2	-11	-9
Other						
Disturbed or Cleared Lands	27	84	84	+57	+57	-0
TOTAL	**719**	**635**	**607**	**-90**	**-114**	**-27**

*Coverage in acres
** Since swamp hardwood, stream swamp and cypress communities could not be accurately distinguished in the 1940s photographs, these subcategories were combined to provide a basis for comparison.

Results show that the watershed was relatively undeveloped in 1940. The most obvious features are the extensive freshwater swamp and mangrove swamp forests, the abundance of wetlands associated with sloughs and wet prairies, and the lack of urban development throughout most of the watershed.

According to the 1940 U.S. Census, the Town of Jupiter contained 215 residents (**Table B-3, Appendix B**). Interstate 95 and the Florida Turnpike had not yet been constructed. The major roads at that time were Center Street, SR 706 (Indiantown Road), SR 710 (Beeline Highway), U.S. Highway 1, SR 708 (Bridge Road) and Northlake Boulevard. Although the C-18 had not yet been constructed, there was evidence of ditching from the Loxahatchee and Hungryland Sloughs to the River. The Jupiter Inlet was open in the 1940 photograph, but the presence of sandbars probably reduced the amount of saltwater coming in during high tides. The inlet was not permanently stabilized for navigation until 1947. On the Northwest Fork, tides, winds and periodic storm events may have had sufficient effects upstream past the mouth of Kitching Creek to promote growth of what appear on the photographs to be mangroves along the northern river bank, extending upstream to river mile 7.8. In **Figure B-2 of Appendix B,** the 1940s distribution of the swamp hardwood (dominated by cypress) community is color-coded green, while mangroves are color-coded orange. This coverage represents our earliest photographic record of mangrove and freshwater community distribution. Extensive freshwater communities occur upstream of river mile 6.5 and intermittently downstream to river mile 5.8.

Flow from the three main tributaries of the river and runoff from the surrounding lands feed into the northern loop of the river, while the uplands and sloughs provide a network of interconnecting lakes, ponds and wetlands (**Figure B-1, Appendix B**) that feed into the tributaries. There are extensive wetlands (prairies and four major sloughs) between Kitching Creek, the North Fork and Bridge Road at the north end of JDSP in Martin County. Two of the sloughs appear to connect the North and Northwest Forks. These four areas historically may have provided surface water flows to the river, but only Wilson Creek is still connected to the river.

Table 1 (see also **Figure B-2** in **Appendix B)** shows that in 1940, there were about 163 acres of mangroves and 467 acres of cypress and stream swamp within the floodplain. Of the total 719 acres of floodplain vegetation identified in the 1940 aerial photography, 65 percent was represented by stream swamp and cypress and mangroves represented about 23 percent. Disturbed or cleared land represented 27 acres or about 4 percent of this coverage and the remaining 8% consisted of inland ponds and slooughs and cabbage palms. Mangroves dominated the floodplain between river miles 4.5 and 6.0 and were present up to river mile 7.8. Stream swamp and cypress were present upstream from about river mile 6.5 and were dominant above river mile 8.0.

1985 and 1995 Vegetation Communities

Beyond the publicly owned lands and agricultural fields, the eastern portions of the Loxahatchee River Watershed were highly urbanized by 1985 and 1995 (see **Figure 8** on page 48). A 1999 census estimate showed the Town of Jupiter with a reported population of 33,925 residents within the city limits. Jupiter residents plus neighboring municipalities accounted for a population of 77,484 residents (**Table B-3, Appendix B**). This number, however; does not include the residents of unincorporated Palm Beach County in the western portion of the watershed (e.g. Jupiter Farms). According to the Palm Beach County Planning and Zoning

Department records, the 1999 census estimated an additional 10,506 residents in Jupiter Farms and 3,536 in Palm Beach Country Estates. Interstate 95 and the Florida Turnpike stand out as major features that bisect the landscape along with extensive areas of agriculture (primarily citrus and cattle grazing), and the 11,471 acres of JDSP.

The most striking features noted in the comparison between the 1940 photos and those taken in 1985 and 1995 were (a) the dredging and filling of former mangrove islands between river miles 4.5 and 5.5; (b) the loss of floodplain and wetlands due to apparent flow diversions, invasion of upland species and development; and (c) the effects of the placement of bulkheads along both shorelines of the estuary and lower Northwest Fork. Also, the islands and oxbows appear to have been heavily scoured over the years. These changes are reflected in total acreage differences between the 1940, 1985 and 1995 coverages. There is an overall loss of approximately 114 acres (17%) of wetland/floodplain area during this 55-year period (**Table 1**).

Figures B-3 and B-4 of Appendix B illustrate the 1985 and 1995 distributions of vegetation within the floodplain. Color infrared photography allowed for the identification of a greater number of plant categories and better observation of vegetative changes. The 1985 photo represents the distribution of vegetation at the time that the Loxahatchee was designated as Florida's first Wild and Scenic River. Whereas in 1940, mangroves were dominant between river miles 4.5 and 6.5 and were present up to RM 7.8, mangroves became dominant between river miles 5.5 and 8.7 and extended upstream to RM 10.4 by 1985. The floodplain in 1985 included 163 acres of mangroves, which represented 25 percent of the vegetation coverage in the Northwest Fork, and 389 acres of freshwater vegetation, representing approximately 61 percent of the coverage (**Table 1**). Therefore, between 1940 and 1985, there was about a 10 percent loss of freshwater vegetation and a 4 percent increase in mangroves within the floodplain area. One would suspect that mangrove encroachment should be higher; however, between 1940 and 1985, there was a loss of mangroves reflected in the category Disturbed and Cleared Land, which increased from 4 percent in 1940 to 13 percent in 1985. Also, the floodplain decreased in acreage from 719 acres to 635 acres.

There were no major changes in coverage between 1985 and 1995 (**Tables 1** and **Figures B-5** and **B-6** in **Appendix B**). This relative stability of plant communities may be attributed to two factors. First, in 1987 additional culverts and operational criteria were added to G-92 to reconnect the Loxahatchee Slough with the Northwest Fork, resulting in more water being added to the Northwest Fork (see section on *Hydrologic and Salinity Conditions* at the beginning of **Chapter 5**). Second, there was above normal rainfall (**Figure 4**) and flow to the river during the 1990s (see **Figure 19, Chapter 5**). These increased flows may have helped to stabilize the distribution of fresh and saltwater communities.

Both the 1985 and 1995 photographs show apparent changes in the distribution of mangroves and freshwater plant community coverages in the Hobe Grove Ditch and Cypress Creek areas. In 1985 and 1995, mangroves were present within the lower portion of Kitching Creek. Near the mouth of the creek, mangroves appear as forests whereas further upstream they appear as understory vegetation with a cypress/cabbage palm canopy. Areas dominated by cypress appear to be more closely associated with wider floodplains.

Summary

Results of the comparisons of aerial photographs from 1940, 1985, 1995 and other years showed the following:

- 1940 aerial photography of the watershed revealed an abundance of swamps, wet prairies, inland ponds and sloughs. Mangroves were present from river mile 4.5 to river mile 6.0 and extended upstream to river mile 7.8. Freshwater stream swamp and cypress communities were present upstream from river mile 6.5 and were dominant within the floodplain portion of the study area above river mile 8.0, comprising about 73 percent of the vegetative coverage of the Northwest Fork, while mangroves represented 23 percent.
- An apparent reduction in total acreage of the river floodplain between 1940 and 1995 can be attributed to several causes, including scouring of the riverbed, bulkheading, development, and loss of wetland vegetation to transitional and upland species due to flow diversion and lowering of water levels in the watershed. Most of the vegetation changes occurred in the lower and middle segments of the Northwest Fork and were documented by more detailed examination of the area between river miles 6.6 and 8.9 (**Appendix B**)
- By 1985, much of the watershed had been developed with the exception of JDSP. Freshwater communities represented 61 percent of the total coverage. Mangroves represented 25 percent of the coverage and may have extended upstream above river mile 10. Mangroves experienced only a 4 percent increase in overall coverage due to floodplain urbanization. Freshwater communities decreased by 10 percent.
- Freshwater flows to the Northwest Fork increased during the period between 1985 and 1995, due to construction and improved operation of the G-92 Structure and increased rainfall. These changes may account for the fact that only minor differences in vegetation coverage occurred during this ten-year period.
- Improved aerial photography that was used during 1985 and 1995 made it possible to distinguish differences in structure and composition of the freshwater communities. This improved resolution may account for the apparent increase in number of species and apparent loss of cypress dominance along the immediate river corridor upstream of river mile 9. Such changes could also be explained by the impact of saltwater intrusion and decreased surface and ground water inflow.

Wild and Scenic River Designation

In May 1985, a 7.5-mile, pristine portion of the upper Northwest Fork was designated by the U.S. Department of the Interior (USDOI) for inclusion in the Federal Wild and Scenic Rivers System, following designation by the state of Florida as a Wild and Scenic River in 1983 (C. 83-358, Laws of Florida, Approved June 24, 1983). Special consideration should be given to ensure that the watershed surrounding this portion of the river is protected to maintain natural flow conditions, good water quality and high quality natural areas. A number of management goals were developed for this system as identified in the *Loxahatchee River National Wild and Scenic River Management Plan* (FDEP and SFWMD 2000). A goal of particular relevance to the development of river flow criteria is to preserve historic communities and functions, especially the bald cypress community, which includes a number of trees 300–400 years old. The estuary, downstream from the "wild and scenic river," is part of the Loxahatchee River-Lake Worth Creek Aquatic Preserve.

Tributary Inflows

A detailed analysis of freshwater flow delivered to the Loxahatchee River and Estuary is provided in **Chapter 5.** Four major sources (G-92 and the Lainhart Dam, Cypress Creek, Hobe Grove Ditch and Kitching Creek) provide freshwater flow to the Northwest Fork. Of these four sources, the Lainhart Dam, which provides flow to the main stem of the river, is the largest contributor providing between 51 and 56 percent of the flow to the Northwest Fork during the wet and dry seasons. The main stem of the Loxahatchee River originates in the Loxahatchee Slough, a pristine cypress swamp and wet prairie wetland located southwest of the river **(Figure 5**). Outflow from the Loxahatchee Slough travels downstream through the C-14 Canal (C-14) and G-92 structure and over the Lainhart Dam to the Northwest Fork of the river.

The second largest contributor is Cypress Creek (26–32%), followed by Kitching Creek (11–13%) and Hobe Grove Ditch (5%). In terms of average dry season flows, the Lainhart Dam provides about 70 cfs; Cypress Creek, 32 cfs; Kitching Creek, 16 cfs; and Hobe Grove Ditch, 7 cfs, for an average total of 125 cfs of freshwater delivered from the Northwest Fork of the river to the Loxahatchee Estuary (see **Table 23** in **Chapter 5**).

In terms of water management, the G-92 structure (upstream of the Lainhart Dam) represents not only the largest source of water delivered to the Northwest Fork, but also the only structure that can be operated by the District to increase or decrease flows delivered to the river. Flows received from Kitching Creek are currently unregulated and are largely rainfall driven. Cypress Creek and Hobe Grove Ditch have water control structures that are operated by the Hobe-St. Lucie Conservancy District.

Hobe Grove Ditch was constructed over a historical flowway known as Moonshine Creek, and then dredged through uplands to the river in the 1960s. Water is held upstream in this system to provide recharge for irrigation wells; hence very little water is released through the structure except when flooding occurs in the groves. Cypress Creek is a primary drainage outlet for the southern portion of Pal-Mar. The water control structure helps to slow the flow from this system and hold more water upstream.

Downstream Areas

Historically, the inlet periodically opened and closed to the sea as a result of natural events. The inlet was kept open by flows from the Loxahatchee River, Lake Worth Creek and the southern part of the Indian River Lagoon. Near the turn of the century, some of this flow was diverted by creation of the ICW and the Lake Worth Inlet, and by modification of the St. Lucie Inlet (Vines 1970). Subsequently, Jupiter Inlet remained closed much of the time until 1947, except when periodically dredged. After 1947 it was permanently opened, and is presently maintained by periodic dredging (USACE 1966).

In the early 1900s, the inlet was artificially opened on several occasions. In 1921, the Jupiter Inlet District (JID) was established and provided oversight for dredging of the inlet in 1922, 1931, 1936 and every few years after 1947. Dredge and fill operations have also been carried out in the estuary embayment and forks. In the early 1900s, placement of fill at the present site of the railroad bridge narrowed the estuary at that location from about 1,200 feet to 700 feet. In the mid-1930s to about 1942, sediments were removed from areas around this bridge and used for roads and construction. In 1976–1977, an additional estimated 30,000 cubic yards were removed from the estuary at the bridge and from an area to the west extending about 600 feet. Some dredging was done in the Southwest Fork near C-18 in the late 1960s and early 1970s. In 1980, three channels were dredged in the central embayment area and an estimated 30,000 cubic yards of sediment were removed (McPherson et al. 1982).

Processes of sedimentation and erosion undoubtedly still have a profound influence in the estuary. A large horseshoe-shaped sand bar, which developed in the central embayment area over the 20 years period from 1960 to 1980, is an example of how sediment transport and deposition continue to alter bathymetry of the estuary (McPherson et al. 1982).

The United States Geological Survey (USGS) measured the volume of incoming and outgoing tides within the Loxahatchee Estuary for several days in 1980. Thirty-nine percent of the incoming tide went into the north arm of the Intracoastal Waterway on August 27. On average, 57 percent of the incoming tidal water at the inlet flowed into the Loxahatchee Estuary west of the Alternate A1A Bridge. The volume of water that enters the estuary during an incoming tide is called the tidal prism and can be estimated based on the following equation:

$$P = A \times T + F \times I$$

where: P is the tidal prism volume, A is the surface area of the estuary west of the Alternate A1A Bridge (1,280 acres), T is the tidal range, F is the area of the floodplain inundated at high tide (256 acres), and I is the average depth in the floodplain at high tide (about one-half foot) based upon observations. Using this equation, McPherson et al. (1982) calculated the tidal prism for the Loxahatchee Estuary for three days in 1980 when the direct total discharge was measured at the Alternate A1A Bridge. The mean tide range for the 1979 and 1980 water years was 2.42 feet and the mean tidal prism was estimated to be 3,226 acre-feet. This volume represents about 63 percent of the total volume of the estuary west of Alternate A1A. In a related study, Chiu (1975) reported that 45 percent of the tidal flow entered the Loxahatchee River Estuary, while 55 percent enters the northern and southern branches of the Intracoastal Waterway.

These data indicate that freshwater inflow to the Loxahatchee River Estuary is very small in comparison with tidal flow. Dry season freshwater inflows from the major tributaries represented only about one percent of the tidal inflow at the A1A Bridge on April 16 and August 26 and 28, 1980 (McPherson et al. 1982). Total freshwater inflow from the same tributaries during the wet season (May to September 1980) represented about five percent of the total tidal discharges at the Alternate A1A Bridge based upon the mean tidal prism. Of this total freshwater inflow (52,870 acre-feet), 77 percent was discharged into the Northwest Fork, 21 percent into the Southwest Fork from the C-18 and two percent into the North Fork (McPherson et al. 1982).

Central Embayment

The central embayment is shallow with an average depth of 3.5 feet, maximum depth of 15 feet and an area of 380 acres (Russell and McPherson 1984; FDEP 1998; Antonini et. al. 1998). The central embayment is dominated by tidal changes. Physical changes in the estuary, such as permanent opening of the Jupiter Inlet, dredging of main channels, expansion and contraction of the opening at the Florida East Coast Railroad trestle and water control structure management have influenced salinity regimes in the estuary (Law Environmental, Inc. 1991b).

In terms of freshwater flow, the central embayment receives on average about 283 cfs (560 acre-feet/day) of freshwater from all surface sources during the wet season conditions (**Table 23, Chapter 5**). This amount is reduced by about 34 percent during the dry season to 187 cfs (370 acre-feet/day. Inflows to the central embayment are highly influenced by releases from S-46, which can release water up to 3240 cfs during extreme flood events.

Oyster reefs in the central embayment contain small and mostly relict shells, and are associated with shoals near points, sandbars and mangrove islands. Thinning, narrow bands of seagrass were observed along the shoreline of the upper central embayment and three tributaries (Law Environmental, Inc. 1991a). Historical evidence indicates that this section of the estuary had highly variable salinity regimes, because of the periodic opening and closing of the Jupiter Inlet due to natural events.

The central embayment contains viable seagrass and oyster communities, which indicates that this area receives sufficient freshwater flow to encourage growth of oysters, while at the same time, there is a need to avoid excessive freshwater discharges that will destroy these biological communities. Maintenance of a salinity regime in the range between 15 and 30 parts per thousand (ppt) should meet these general requirements. Monitoring is needed to ensure that any proposed dredging in the inlet and the embayment area does not result in further saltwater intrusion. West of the bridge crossings, from river miles 2.0 to 2.5, the central embayment of the Loxahatchee Estuary divides into three branches -- the North, Northwest and Southwest Forks **(Figure 2).**

North Fork

The North Fork is a very shallow tributary and presently contributes only a small percentage of the total freshwater flow to the estuary (Russell and McPherson 1984; Sonntag and McPherson 1984). Estuarine conditions extend approximately 5 miles up this branch from the mouth of the Inlet (McPherson and Sabanskas 1980). The North Fork of the estuary has an average depth of 3.4 feet, maximum depth of 6.6 feet, an average width of about 0.15 miles and covers a total area of about 200 acres. Freshwater flow to the North Fork is uncontrolled. Russell and McPherson (1984) indicated that freshwater flow from the North Fork represented only about 2 percent of total freshwater flow to the estuary. Much of the upper end of the watershed of the river lies within JDSP. The shoreline along the lower estuary is surrounded by residential development and most of the shore is bulkheaded. The sediments generally consist of fine sand and mud. Some areas have very deep pockets of soft mud that has a high content of organic material. Water quality is often poor due to high levels of turbidity and color that limit light penetration, low levels of dissolved oxygen (DO) and occasional high concentrations of fecal coliform bacteria (Dent et al. 1998). Due to the low input of freshwater, bottom salinities in the lower section of the North Fork are generally above 25 ppt, while salinities further upriver average about 14 ppt.

Management considerations in the North Fork include the need to improve water quality conditions. Reduction of turbidity levels and suspended solids would help increase light penetration to encourage growth and development of seagrasses. Retrofitting of existing storm water systems or other actions that can help reduce turbidity would also be beneficial to oysters, other benthic invertebrates and fish populations. Any steps that can be taken to remove or stabilize the soft organic sediments will help to reduce turbidity and improve biological conditions. Although there is no direct control over freshwater inflows to this reach of the estuary, any actions that can be taken to improve flushing and exchange of water with the North Fork estuary should be encouraged as a means to improve water quality.

Northwest Fork Estuary

The Northwest Fork of the Loxahatchee Estuary has been less impacted than the Southwest Fork, but has been considerably altered from its original condition due to development of the shoreline and dredging. The estuarine portion of the Northwest Fork extends from the central embayment north and west for approximately 2 miles to a point (near river mile 4.5) where the estuary constricts to form the river channel (**Figure 2**). This area has an average width of about one-half mile, depth of 4.2 ft, maximum depth of 12.5 ft, and contains an area of about 320 acres. Brackish water conditions can extend for many miles upstream, depending on flow. For this analysis the dividing line between the river and the estuary is approximately river mile 5, which is located downstream from JDSP. This section of the estuary receives the direct outflow from the Loxahatchee River and thus may experience large and rapid fluctuations in salinity. The Northwest Fork originally drained most of the Loxahatchee basin and still provides, on average, about 65–67 percent of the total freshwater flow to the estuary. During dry periods, as much as 89–94 percent of the total flow to the estuary is derived from the Northwest Fork (**Table 24, Chapter 5**). Generally the waters remain saline during most of the year due to saltwater inflow from the inlet.

Flows from the Northwest Fork of the Loxahatchee River historically were sufficient to maintain the estuary as a brackish water system that supported diverse estuarine fish, benthic fauna and oyster communities in its upper reaches and more marine seagrass communities downstream near the juncture with the central embayment. Bottom salinities in the Northwest Fork Estuary generally remain above 25 ppt. Bottom salinities are fairly stable in the range from 20 ppt up to 35 ppt during typical wet season conditions. The water column can be highly stratified, however so that freshwater may be present at the surface. Salinities throughout the Northwest Fork may decline below 10 ppt during extreme discharge events (Russell and McPherson 1984).

Southwest Fork

The Southwest Fork (**Figure 2)** has been heavily altered, dredged and channelized (McPherson et al. 1982). The Southwest Fork is important for navigational and recreational use because it provides access to local marinas and private homes. It also provides a mixing zone for freshwater discharges from C-18 before they reach more sensitive grass beds and oysters located further downstream.

Freshwater discharges to this waterway, with the exception of a couple of small creeks, are controlled by S-46, an automated structure providing overflow from Canal C-18. Salinity is influenced in the Southwest Fork primarily by the S-46 structure in C-18 (FDEP, 1998). The lower segment of the Southwest Fork extends for about 0.7 miles from its junction with the central embayment to the eastern end of the C-18, has an average width of 0.16 miles, depth of 5.5 ft and covers an area of about 70 acres. The C-18 is reported to drain approximately one-half of the entire Loxahatchee watershed (Hill, 1977) and the S-46 water control structure prevents saline waters from moving upstream beyond river mile 4.8. Estuarine conditions occur in the C-18 for a distance of about 1.5 miles below the base of S-46. This portion of the canal has an average width of about 220 feet, depth of 10 ft and an area of about 40 acres. The Southwest Fork represents about 7 percent of the total estuarine area of the Loxahatchee River system west of the Alternate A1A Bridge. Discharges from C-18 through the Southwest Fork provide about 33 percent of the total freshwater inflow to the estuary **(Table 2**). Periodically, very large discharges of floodwaters ranging upwards from 1,000–3,000 cfs occur from the C-18 Basin that turn much of the estuary into freshwater. In contrast, during dry periods there are long periods of time when the estuary receives no flow from C-18.

The Town of Jupiter Water System operates a reverse osmosis (RO) water treatment plant that produces a concentrate solution as a waste product that is discharged to the C-18 at the Central Blvd. Bridge, downstream of the S-46 structure. The RO concentrate salinity is typically about 16 ppt, and is less saline on average than the receiving water. The current plant is permitted to discharge up to 4 million gallons per day (mgd) of RO concentrate from water obtained from the Floridan Aquifer, and currently discharges an average of 2.0 MGD. The current permit allows a mixing zone of 400 meters on each side of the outfall. This water flows to the estuary in an area of Class II surface waters (shellfish harvesting), although no harvesting is conducted now. Total ammonia concentrations average approximately 2.5 milligrams per liter (mg/l), and have been reported as high as 7 mg/l. The Town of Jupiter and the DEP have agreed to work together in assessing any impacts from the RO concentrate during the upcoming Total Maximum Daily Load (TMDL) review [Letter from Tom Swihart (FDEP) to SFWMD, June 18, 2001]. Additional RO concentrate is released by the Village of Tequesta Water Treatment Plant near the northeast side of the US Highway 1 Bridge, just downstream of the embayment area. This release is relatively new and does not appear to be causing any problems, due to the presence of strong currents in this area near the inlet.

The Southwest Fork historically was an estuarine system that probably maintained slightly higher salinities than the Northwest Fork Estuary, supporting both oyster and seagrass bottom communities. Bottom salinities in this portion of the estuary generally remain above 25 ppt except during periods when large amounts of water are discharged from C-18.

THE LOXAHATCHEE ESTUARY

Physical Features

Inlet Configuration/Coastal Influences

Key events in the history of hydrological alterations of the estuary include the creation of the ICW in the late 1800s and early 1900s by dredging the connection between Lake Worth and the Jupiter Inlet, continuing into Biscayne Bay to the south (Russell and McPherson 1984). The Lake Worth Inlet was also constructed and modifications to the St. Lucie Inlet during this period further diverted flows away from the Jupiter Inlet. Fill added to the present site of the Florida East Coast Railroad trestle reduced the cross-sectional area of the river mouth in the early 1900s (Wanless et al. 1984). Past measurements and calculations indicate that 56 percent of the tidal flow enters the northern and southern branches of the ICW (Chiu 1975). Other activities being equal, those projects that tend to increase tidal exchange and prism, and decrease shoaling of the Jupiter Inlet, should produce a saltier system in the Loxahatchee Estuary by increasing tidal exchange and decreasing the residence times of freshwater within the system.

Drainage Alterations

In total, drainage alterations have rerouted flows to reduce the effective size of the Loxahatchee Basin and therefore total runoff (McPherson and Sabanskas 1980). These drainage alterations primarily serve to deliver freshwater runoff to the estuary more rapidly and abruptly, flushing the estuarine portions with higher maximum flows. During periods of dry weather, however, drained marshes and lowered water tables are not able to provide the same historic base flows of freshwater to prevent upstream encroachment of saline estuarine waters (Rodis 1973; Alexander and Crook 1975). Overall lowering of the water table throughout the watershed due to canal construction and the need to maintain lower water levels to protect subsequent land development have resulted in a net loss of an estimated 8,000 acre-feet of storage in the C-18 Basin (SFWMD 2002).

Various proposals have been developed and actions implemented to increase the amount of freshwater flow from the Northwest Fork or reduce the upstream movement of saline water. These proposals include a modification of the release schedule from S-46 to permit discharge only during large storms, installation of an additional culvert at G-92 and construction of physical barrier or weir across the Northwest Fork (FDNR 1985; Birnhak 1974). The capacity of G-92 was increased in 1987. Due to this increased capacity, revised operating criteria and abnormally high rainfall conditions during eight of the past ten years (**Figure 4**), the average amount of water released to the Northwest Fork over the last decade has increased. This increased flow, however, has not been sufficient to protect the river from the periodic upstream movement of saltwater during dry periods, or to substantially alter salinity conditions in the estuary.

Shorelines

Shorelines near the Florida East Coast Railroad trestle and in the central embayment are mostly altered upland and wetland areas, although there are some remaining areas where natural upland fronts the water. Above the river delta, shorelines are heterogeneous, with mixed uplands, wetlands and filled areas. Much of the JDSP shoreline is undeveloped wetland and upland shoreline that fronts directly on the river.

In a 1990 survey, hardened shorelines, including bulkhead, rip-rap and debris-filled banks, occupied most (about 65%) of the downstream reach (river miles 0.9 to 2.0) and more than 60 percent of the shore was hardened to river mile 4. The relative amount of hardened shore declined by approximately half in each successive mile of the Northwest Fork. Overall, about 37 percent of the shoreline of the Northwest Fork was hardened, compared to 51 percent in the North Fork and 12 percent in the Southwest Fork. Shoreline hardening increases with river mile in the North Fork, but declines once the stream enters the Park (Law Environmental Inc. 1991a).

Sediments

The uppermost sediment veneer in an estuary controls and/or affects sediment resuspension, exchanges of oxygen and nutrients between the water column and bottom, and the number and kinds of animals living in and on the bottom. The types of bottom sediment in the Loxahatchee River Estuary vary with water depth, flow characteristics, location in the estuary and biological community.

Sonntag and McPherson (1984) observed that fine sand is predominant throughout much of the estuary. Shell debris, larger than sand size, comprises less than one percent of the sediment except on oyster bars where it is abundant. Silt, clay and organic matter are least abundant in the channels and on sand bars, somewhat more abundant in adjacent seagrass beds, and in greatest abundance in the black to gray sediments that occur in the estuary. Soft, black sediments, which are common in the deeper waters of the estuary, contain the largest percentage of clay, silt and organic matter. Black and gray sediments range in thickness from a few inches to several feet.

Law Environmental Inc. (1991a) noted that the central embayment contains sediments that are white in color on the surface, but sediments 2.0 centimeters (cm) or more below the sediment surface are blackened over large areas. In general, top sediments of the central embayment contain less than 10 percent silt and clay whereas in the three tributaries sediments usually range from 10 to 50 percent silt and clay. The upper reach of C-18 contains a higher proportion of silt and clay (65–74%). The Northwest Fork has low amounts of fine surface sediment in the mangrove-forested area and at the river delta. Deposition of fine organic matter has been observed in deep holes in the side channels of the main stem of the river. The two river deltas contain coarse sediment throughout due to peak-flow deposits and bed transport. The tidal delta sediments are much finer at depth because of oceanic material that is deposited in the inlet. Sediments in the shallow areas off Pennock Point (**Figure 2**) had unusual color and texture, indicating that these mudflats are sites of lateral ground water movement into the estuary (Law Environmental Inc. 1991a).

Salinity

Those regions with the highest variability of surface and bottom salinities are presumably most responsive to hydrologic variables, such as tide stage and discharge. In general, surface salinity is most variable between river mile 2.6 and river mile 6.9, while bottom salinity is most dynamic between river miles 5.0 and 8.0 (**Figure 2**). The station at river mile 5.0 experiences both extremely saline and extremely fresh conditions. Stratification is prominent between river miles 2.6 and 8.0 and is usually at a maximum at river mile 3.7. Little vertical stratification generally occurs below the confluence of the three forks (Law Environmental Inc. 1991a)

Biological Resources

Biological resources of the Loxahatchee River Estuary are greatly affected by freshwater and tidal flow and by human activities. In undisturbed estuaries in south Florida, mangrove forest, oyster bars and seagrass beds constitute major biological communities in brackish and saline environments. Mangroves are abundant in the upper reaches of the Northwest Fork of the Loxahatchee Estuary. Marshes are few and small in size, and are usually limited to a narrow fringe of emergent grass species seaward or landward of mangroves, or growing along upland shorelines. Seagrass communities are present in the central embayment and oyster bars grow in the estuary where there is suitable, undisturbed substrata and adequate tidal flow and salinity.

Mangroves

Mangrove-swamp, consisting primarily of red mangroves (*Rhizophora mangle*) with occasional white mangroves (*Laguncularia racemosa*) is the dominant natural feature along the shorelines of brackish-water areas of the Northwest Fork. “Forests” of mangrove only occur in Jonathan Dickinson Park. Elsewhere, mangroves grow as thin borders along natural shorelines, filled banks or in front of hardened shorelines. In the Loxahatchee River Estuary, mangrove forest is most extensive in the Northwest Fork. Small stands of mangrove occur in the upper reach of the North Fork, in the central embayment, in Jupiter River and other small tributaries and on several islands. Mangroves along the Northwest Fork range from brackish water estuary conditions near the eastern edge of Jonathon Dickinson Park at river mile 6 into predominantly freshwater environments and are eventually replaced by a floodplain swamp community (dominated by cypress) by river mile 10.

Mangroves are very salt tolerant and tend to colonize shorelines where the substrate has been stabilized or protected from the effects of wave action or erosion. The continued spread of mangroves upstream in the river floodplain, displacing less salt tolerant species, such as cypress and hardwoods, has been viewed as an impact to the ecosystem. These slow changes in river vegetation communities are linked to the combined effects of saltwater intrusion caused by the permanent stabilization of Jupiter inlet, dredging of the estuary and construction of C-18.

Even though the spread of mangroves into formerly freshwater environments is viewed as an adverse condition for the river, mangroves serve an important role in the estuary ecosystem, since these plants provide a stable substrate for many other species to colonize (Savage, 1972). Mangroves are also a significant source of primary productivity and the physical and bacterial decomposition of mangrove leaf litter provides a major food source for detritivores in the estuary food chain (Heald and Odum, 1970). Mangroves are susceptible to frost damage and may be completely destroyed during a hard freeze.

Submerged Aquatic Vegetation

Four species of seagrasses are commonly observed in the Loxahatchee Estuary. Shoal grass (*Halodule wrightii*) tends to be the most abundant species. Stargrass (*Halophila* sp.) sometimes occurs with shoal grass, but its biomass tends to be insignificant except in localized areas. The presence of Johnson's seagrass (*Halophila johnsonii*) in the Loxahatchee Estuary was noted by Kenworthy (1992). Manatee grass (*Syringodium filiforme*) and turtlegrass (*Thalassia testudinum*) occur rarely in the estuary. The distribution and composition of seagrass communities changes considerably from year to year. Shoal grass has the broadest salinity tolerance, followed by turtle grass and manatee grass. *Halophila* spp. are the most stenohaline species of those in the study area (Zieman, 1982). Turtlegrass has an optimum range of 24–35 ppt. Salinity, temperature and water clarity are quite variable in the estuary compared with the north arm of the ICW, where inflow of ocean water maintains relatively high salinity, moderate temperature and relative high water clarity. Manatee grass and turtlegrass are dominant under these conditions and form dense stands just north of the estuary in the north arm of the ICW.

At the time of the survey by McPherson et al. (1982), shoal grass was the dominant species, extending from slightly above to several feet below the low tide line. The largest area of shoal grass, about 70 acres, occurred in the eastern part of the central embayment. The biomass diminished in the western part of the central embayment and in the forks of the estuary. Only sparse growth was observed in 1980 near Pennock Point, which is located at the juncture between the central embayment and the Northwest Fork.

During a 1990 survey conducted by Law Environmental, Inc. (1991a), the highest density of seagrass distribution occurred near the inlet, with heavy growth on shoals and bars. Thin, narrow bands of grass were observed along the shorelines of the upper central embayment and the three tributaries. The best, developed fringing beds were along Pennock Point. No beds were found upstream of the mouth of the Southwest Fork. Grasses were found in isolated patches along the western shore of the Northwest Fork, immediately upstream of Pennock Point. Grasses grew in a narrow, thin strip along both banks of the North Fork to the Tequesta Drive Bridge.

Shoal grass is the dominant seagrass species upstream of the Florida East Coast Railroad trestle. It extends from the trestle area to the limits of seagrass distribution in each tributary. Other species occurred in large to small uniform beds, or patches within shoal grass beds, between the Florida East Coast Railroad trestle and Anchorage Point. Moving upriver from the trestle, star grass ended first, and then turtle grass and manatee grass, at about the same river location. Small areas of turtle grass occurred upstream along the southern shore of the central embayment, almost to the mouth of the Southwest Fork. Small areas of manatee grass were found along the west bank of the Northwest Fork. None of the grasses grew in depths of water greater than about six feet at low tide. The species most often found in the deeper areas was shoal grass. The seagrass species that are less tolerant to freshwater (i.e., turtle, manatee and stargrass) grew on level, shallow and often white-colored sands (Law Environmental, Inc. 1991a).

Law Environmental, Inc. (1991a) compared their data to previous studies and noted that significant changes had occurred in the distribution and abundance of seagrasses in the estuary during the past 10 years. Some of these changes could be attributed to seasonal variation, differences in techniques or mapping errors. In spite of these differences, a large area of seagrasses between the channel and south shore apparently disappeared over a five-year period from 1980 to 1985 and grasses (mostly shoal grass) colonized sand bars that were not vegetated in 1980–1981. Species composition also changed from 1985 to 1990. Deeper water fringing beds of star grass were not conspicuous in 1990. Manatee grass extended its range, with expansion into former shoal grass beds in the lower part of the central embayment, or upriver to about river mile 2.5. These changes may have been the result of succession, encouraged by stable, relatively high salinities in the eastern end of the central embayment. This corresponds to a river reach where mean bottom salinity was greater than 30.0 ppt and variance was low. The western portion of the embayment was an area of high turbidity and few seagrasses, but with some oysters, suggesting transitional conditions.

A waterway evaluation study conducted by Antonini et al. (1998) included data collected in 1994, 1996 and 1998. These data indicated that seagrass communities in the middle of the central embayment shifted significantly between sampling periods, presumably in response to changes in sediment composition and distribution, river flow and perhaps boating activity. Their data also indicated that seagrass communities (species not listed) occupied the lower reaches of the North, Northwest and Southwest Forks in areas that did not contain seagrasses in 1982.

A recent survey by Ridler et al. (1999), which included one site in the central embayment, showed moderate changes in distribution of seagrasses at this location relative to the data collected by Antonini et al. (1998). More importantly, Ridler et al. (1999) found that Johnson's seagrass (*Halophila johnsonii*) was more abundant than shoal grass at the site they sampled. A subsequent study conducted in the summer of 2000 at their study site in the central embayment showed that overall seagrass distribution increased from 32 percent bottom coverage to 70 percent bottom coverage, relative to the 1998 study. However, the coverage of Johnson's seagrass declined from 43 percent to 10 percent during that same period (Ridler et al. 2000).

Because of its limited geographical distribution (i.e. Sebastian Inlet to northern Biscayne Bay), National Marine Fisheries Services published a rule on September 14, 1998, which listed Johnson's seagrass as a threatened species. A threatened species recovery team was convened in February 1999 to prepare a recovery plan and develop recommendations for critical habitat for this species. One of the 10 sites identified as essential habitat is located just within Jupiter Inlet and the Loxahatchee River. The recovery team established five criteria for establishing this designation, which included: (1) populations which have persisted over 10 years; (2) populations with persistent flowering; (3) locations at the northern and southern range limits; (4) populations with unique genetic diversity; and (5) core locations with a documented high abundance of grass compared to other areas in the species' range. The 4.3-acre site located just west of Dubois Park near the entrance to Zeke's Marina will continue to be monitored as a part of the recovery plan (National Marine Fisheries Service 2000). Any proposals to alter flow conditions in the Northwest Fork to the extent that they may impact the local population of Johnson's seagrass, will have to be reviewed and approved by the National Marine Fisheries Service.

Oysters

Periodic tidal exposure, sediments and water quality influence oysters and their associated fauna. Oyster spawning depends on salinities greater than 7.5 ppt and spat grow best above 12.5 ppt; the optimum range of salinity for adult oysters is 10–28 ppt and lower salinities repel marine predators (Sellers and Stanley 1984). In the Loxahatchee Estuary, oyster reefs grow mostly in intertidal and shallow subtidal areas. Oysters also grow on rip-rap, seawalls and bridge piers. Islands upstream of the Northwest Fork River delta (river mile 4) are fringed with oysters growing on red mangrove roots. Reefs grow as point bars, usually on the downstream ends of the mangrove islands. In 1990, reefs were present in the Southwest and Northwest Forks but were rare in the North Fork. Reefs in the central embayment are small; contain mostly relict shells; and are associated with shoals, point-bars and mangrove islands (Law Environmental, Inc. 1991a).

Field observations in the Loxahatchee Estuary (Law Environmental, Inc. 1991a) showed that oysters were smallest at upstream and downstream locations and largest in the central part of their range. In the Northwest Fork, the largest living oysters (standard length 80–90 millimeters) occurred between river miles 4.0 and 6.0 (**Figure 2**), where average high tide surface salinities were between 7 and 22 ppt, and ranged from about 2 to 28 ppt. The river delta (“S-Bar”), located at approximately river mile 4.5 (**Figure 2**), played a controlling role in upriver salinities and was the most active oyster ground (Law Environmental, Inc. 1991a).

Benthic Macrofauna

Various surveys of macrofauna have been conducted in the estuary (McPherson et al., 1984, Strom and Rudolph 1990, Law Environmental, Inc. 1991a, Dent et al., 1998). McPherson et al. (1984) studied fouling organisms in the estuary and noted that two of eight barnacle species occurred only in marine salinities, while other species occurred in lower salinities. Only one species occurred as far upstream as the JDSP. Overall, diversity, density and growth of fouling communities are greater in high salinity areas, greater before the summer wet season, and higher after tropical storms. Strom and Rudolph (1990) observed that representatives of brackish fauna occurred as far upstream as the Trapper Nelson site (river mile 10.7), although most of the species at this location were typical of freshwater environments.

Samples collected by Law Environmental, Inc. (1991a) from oyster reef communities in the estuary contained a total of 41 invertebrate taxa within seven phyla. Analyses of these data indicated that four taxa had a broad distribution along the river and occurred upriver to the limit of their survey within JDSP. Almost a third of the taxa were marine species, requiring high salinities that occurred no farther upstream than the oyster reef at the mouth of the Southwest Fork. Based on distribution and abundance of oysters and associated macroinvertebrates, the authors concluded that salinities in the central embayment were high (>30 ppt), with a narrow range, and salinities near the river delta are lower (3–20 ppt) with a wide range. Salinities near JDSP were generally below 20 ppt and eventually fall to near zero at river mile 7 (**Figure 2**), suggesting that brackish conditions occur between the river delta and the Park. A recent status report on ongoing studies (Dent et al., 1998) listed 410 taxa that occur in the estuary and adjacent waters. The locations of estuarine stations sampled and the major species collected in these samples are shown in **Table 2** and **Figure 6.**

Table 2: Synopsis of General Taxonomic Composition 1992–1997 (from Dent et al., 1998)

Station	Abundance (total mean)	annelid	crust	mollusc	Other	Total # of Species	Dominant Taxa'	Genus species	Mean total taxa	Mean diversity (Shannon -Wiener)	Mean % dominant
41	*2812*	*54*	*36*	*64*	*4*	*73*	*Pelecypoda*	*Macominae unid,*	*23*	*2.92*	*60.96*
							Polychaeta	*Pnonospio sp.*			
							Oligochaeta	*Tubificidae unid.*			
							Polychaeta	*Polydora socialis*			
							Polychaeta	*Scolelepis texana*			
60	*1599*	*39*	*41*	*15*	5	*85*	*Tanadacea*	*Hargeria repax*	*18*	*3.34*	*52.94*
							Polychaeta	*Capitella capitata*			
							Nemertinea	*Nernenea unid.*			
							Polychaeta	*Scolelepis texana*			
							Gastropoda	*Caecum pulchellum.*			
70	*2795*	*61*	*22*	*11*	6	*113*	*Polychaeta*	*Streblospio benedicti*	*28*	*3.17*	*77.75*
							Polychaeta	*Capitella capitata*			
							Polychaet	*Branchiomma sp.*			
							Amphipoda	*Grandidierella bonnieroides*			
							Polychaeta	*Lumbrineris verrilli*			
62	1913	17	48	13	22	*76*	*Isopoda*	*Cyathura polita*	*19*	*2.96*	*52.81*
							Diptera	*Polypedilum scalaenum group*			
							Amphipoda	*Grandidierella bonnieroides*			
							Tanadacea	*Halmyrapseudes bahamensis*			
							Tanadacea	*Hargeria repax*			
54	*1605*	*44*	*42*	*4*	*10*	*66*	*Polychaeta*	*Streblospio benedicti*	*13*	*2.32*	*48.62*
							Amphipoda	*Grandidierella bonnieroides*			
							Tanadacea	*Halmyrapseudes bahamensis*			
							Amphipoda	*Ampelisca vadorum*			
							Nemertinea	*Nernenea unid.*			

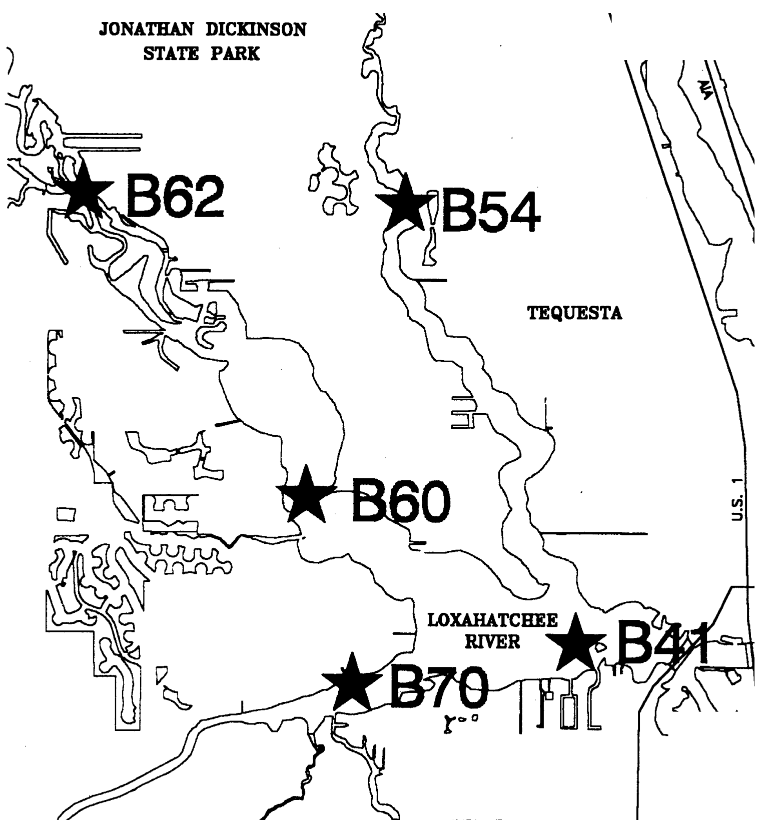


Figure 6. Location of Loxahatchee Estuary macroinvertebrate sample sites used by Dent et al. 1998.

Results of the recent studies (Dent et al., 1998) indicated that the estuarine stations, overall, generally contained fewer taxa than stations located in more marine waters. Estuarine stations contained a larger proportion of crustaceans (44%) than annelids (33%) or molluscs (11%), whereas stations in more marine waters contained a predominance of annelids (58%), about 30 percent crustaceans and 7 percent molluscs. Preliminary analyses of these data, and comparison with data from other studies, suggest that this invertebrate community shows seasonal changes in species composition, short-term changes due to specific rainfall or discharge events and long-term trends.

Several studies have examined fish communities within the Loxahatchee River, including Christensen (1965), Synder (1984) and Hedgepeth (unpublished). Salinity studies have been conducted by Birnhak (1974), Rodis (1973), Chiu (1975) and Russell and McPherson (1984). The Loxahatchee River Environmental Control District has ongoing studies of fishes and salinity as well as invertebrates and seagrasses. Studies of fishes indicate that a significant relationship exists between community composition and salinity on the Loxahatchee River. The upstream area of the river (above river mile 9) is characterized by freshwater species and the lower portion (from the inlet to river mile 5) is characterized by marine and estuarine species.

Fishes

Data from a study of fishes in the Loxahatchee Estuary by Hedgepeth (unpublished) and Hedgepeth et al. (2001) indicate that season of the year, salinity and availability of habitat affect fish abundance, distribution and diversity in the estuary. The dominant fishes in the Loxahatchee Estuary are listed in **Table 3.**

Table 3. Relative Abundance and Ranking of the Most Abundant Fishes in the Loxahatchee Estuary, Based on Samples Collected During 1982–1983 (Hedgepeth et al., 2001).

Species	Specimens Rank	Biomass Rank	Appearance Rank	Sum of Ranks	Overall Rank
Dasyatis americana	16	15	16	47	19.3
Harengula humeralis	8	14	16	38	12.5
Harengula jaguana	2	3	16	21	7
Jenkinsia lamprotaenia	15	16	16	47	19.3
Sardinella aurita	9	12	16	37	11
Anchoa hepsetus	**1**	**2**	**13**	**16**	**3**
Anchoa lyolepis	6	16	16	38	12.5
Anchoa michilli	**3**	**8**	**7**	**18**	**5**
Synodus foetens	16	16	15	47	19.3
Strongylura notata	16	9	6	31	10.5
Strongylura timucu	16	16	11	43	15
Trachinotus falcatus	16	16	12	44	16
Diapterus auratus	16	13	9.5	38.5	13
Eucinostomus argenteus	**4**	**4**	**1**	**9**	**1**
Eucinostomus gula	**10**	**5**	**2**	**17**	**4**
Eucinostomus jonesi	13	16	16	45	17
Gerres cinereus	14	16	16	46	18.5
Archosargus probatocephalus	16	16	14	46	18.5
Lagodon rhomboides	12	10	5	27	9
Leiostomus xanthurus	**5**	**1**	**9.5**	**15.5**	**2**
Mugil cephalus	7	7	8	22	8
Mugil curema	11	6	3	20	6
Sphyraena barracuda	16	11	4	31	10.5
Spheroides testudineus	16	16	10	42	14

Bold text indicates the most abundantspecies abundant species

Peaks of anchovies and herring were noted during the month of February, while sciaenids, anchovies, herring and mojarras peaked in July. These peaks reflected spawning periods for these groups. The seagrass beds of the central embayment, the lower North Fork and lower Southwest Fork tend to support the highest number of species and individuals (**Table 4**). Abundance and diversity were also higher at sites where average salinities were above 25 ppt. At sites where salinities averaged 5 ppt. or lower, the number of species declined significantly. The most abundant species were striped anchovy (*Anchoa hepsetus*); scaled sardines (*Harengula jaguana*); spotfin mojarra, (*Eucinostomus argenteus*); and spot (*Leiostomus xanthurus*).

Table 4. Numbers of Fish Collected in Loxahatchee Estuary as a Function of Salinity (1982–1983)

Station Location	# of Individuals	# of Species	Salinity Mean	Salinity Minimum	Salinity Maximum
Loxahatchee River	258,482	144	15.6	0.0	35.0
Embayment Area	185,936	102	24.6	3.0	35.0
Lower North Fork	20,405	62	21.3	6.0	35.0
Upper North Fork	945	30	3.7	0.0	22.0
Mid-Northwest Fork	911	30	4.6	0.0	19.0
Upper Northwest Fork	869	40	0.4	0.0	4.0
Lower Southwest Fork	49,416	68	9.8	0.0	27.0

Source: Hedgepeth et al. 2001

Manatees

The Florida manatee (*Trichechus manatus*) is an important marine mammal that lives in or seasonally visits the Loxahatchee River system (Packard, 1981). Manatees are protected at the federal level by the Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1973. At the state level they are protected by the Florida Manatee Sanctuary Act of 1978, which establishes the entire state as a refuge and sanctuary for manatees. Manatees are also protected by the Loxahatchee River-Lake Worth Creek and Indian River Lagoon Aquatic Preserve Management Plans (Law Environmental, Inc. 1991b). Recently, the United States Fish and Wildlife Service (USFWS) developed a Manatee Recovery Plan (USFWS 1996). The State of Florida requires 13 counties within the state (including Martin and Palm Beach Counties) to develop individual Manatee Protection Plans for waters within their jurisdictions. The USFWS further identified actions that need to be taken to protect manatees as part of the Multispecies Recovery Plan (USFWS 1999).

The Loxahatchee River (Northwest and Southwest Forks) is considered a high priority water body because this area has a well documented history of manatee use. Manatees are found primarily in the Southwest Fork near S-46, the lower North Fork, Jupiter Inlet (river mouth) and residential canals. Nearby Jupiter Sound has also been identifed as a seasonally important manatee feeding ground. The largest concentrations of manatees occur in October, January and December (Law Environmental, Inc., 1991b). Manatees and their calves have been observed apparently drinking freshwater at the S-46 structure. This area may also be an important nursery area and mating behavior has been observed in this vicinity (Law Environmental, Inc. 1991b). Although manatees can often be seen skimming freshwater off the surface and congregating at spillways and other freshwater sites, ingestion of freshwater in this manner is not a requirement

(USFWS 1996). In general, manatees avoid areas with high boat traffic and tend to migrate upstream into JDSP during rough weather. Concerns have been raised that hydrologic alteration of freshwater flows delivered to the estuary could potentially contribute to changes in the distribution or abundance of submerged aquatic plant communities, a reduction in water quality and/or a reduction in adequate levels of warm water that manatees require (FDEP 1998).

Estuary Water Quality

Water quality in the estuary is a dynamic process. Estuaries are receiving bodies for discharge from tributary rivers and streams and ground water inflow. This water mixes with seawater that is exchanged through the mouth of the estuary and the inlet during daily tidal cycles and is subject to monthly and seasonal changes in flows and tides as well as the effects of severe storm events. Water quality in the estuary is thus highly variable and is subject to potential contamination or degradation of water quality from both directions. Many freshwater and marine organisms periodically use the resources of an estuary during parts of their life cycles and some organisms are highly dependent on the dynamic range of conditions in an estuary to survive. The productivity of an estuary depends upon maintaining a sufficient range of variation, while providing adequate stability of the distribution of this range to prevent undue stress on the organisms that live in these systems.

The nutrients that enter the system from upland runoff, combined with the transition from freshwater to saltwater environment, can result in large concentrations of brackish water organisms that exploit these conditions. Planktonic (floating) organisms generally live near the surface where oxygen concentrations and light levels are highest and tend to move back and forth due to the action of tide and wind. Benthic (bottom dwelling) organisms are generally restricted to particular locations and can be severely damaged by rapidly fluctuating conditions. Nektonic (swimming) organisms can move throughout the estuary and seek out favorable conditions.

Salinity

Freshwater from rivers such as the Loxahatchee contains little or no salt and is less dense than seawater. Freshwater tends to “float” above saltwater, resulting in stratification of salinity and often other water quality conditions unless the water is very shallow or is well mixed by wind or turbulence. Estuaries typically contain a range that varies from very low salinity (less than 5 ppt) near the upstream end to full strength seawater (35 ppt) at the ocean interface. This range of salinities is important because many types of organisms are adapted to utilize particular salinity ranges. The management goal for an estuary should therefore be to provide an appropriate flow regime from the river that, when balanced with the influx of seawater, will create a distribution of freshwater, brackish and marine salinity conditions in the estuary that is seasonally stable and sufficiently extensive so as to maintain the desired species composition.

Nutrients

Estuaries typically receive large amounts of nutrients. Ground water is often high in nutrients, such as nitrogen and phosphorus. Nutrients are also derived from natural breakdown processes in soils and water, by runoff of fertilizers from yards and gardens and from airborne chemicals that enter the water by precipitation and rainfall. The rapid transition from freshwater to saltwater conditions also results in the death of organisms that cannot tolerate the changes, and the rapid destruction of cells and tissues due to osmotic stress. This mortality also contributes to the rapid cycling of nutrients and high productivity that occurs in estuarine environments.

Turbidity and Color

Color is a natural feature of freshwater environments, especially in areas such as marshes and swamps that often have highly organic soils. In such areas, the water is often brown or yellow in color due to the presence of "tannins," which are water-soluble byproducts of decomposition of plant materials. Tannins and other complex organic materials tend to precipitate and settle out when they mix with seawater, often creating a color gradient across the estuary that ranges from brown at one end to blue at the other end. Turbidity is the presence of fine suspended particles in the water that may include organic materials, silt or clay sized inorganic materials or microscopic organisms, such as bacteria, algae and protozoans. Oysters play an important role in these ecosystems because they are filter feeders and tend to remove suspended materials from the water column. Seagrasses and other benthic communities help to reduce turbidity because many of their associated organisms are filter feeders. Additionally, seagrasses tend to reduce the amount of wave scouring that occurs at the substrate-water interface and help to bind together sediment particles to prevent resuspension in the water column.

Oxygen and Temperature

Freshwater entering the system is often of substantially different temperature than the seawater. Any time that such differences exist, there is a potential to increase the effects of stratification. Warmer water also has less ability to hold oxygen. In summer, warmer water from the land, combined with lower salinity, may "float" across the surface of the estuary, resulting in stratification. If this water is also turbid or contains large amounts of plankton, it may block light penetration into the deeper layers. The result is that water near the bottom may contain little or no oxygen. Cooling of water at night may result in better mixing, although the lack of light may cause oxygen concentrations to continue to decline.

Light

Color, suspended materials and the presence of planktonic plants and animals are all factors that reduce the transparency of the water and reduce light penetration. Light is important in the estuary because it controls the ability of plants to photosynthesize -- to produce organic matter and oxygen, while consuming carbon dioxide. If light is absent, oxygen levels will decline. If light cannot penetrate to the bottom due to high turbidity, then seagrasses and algae will die and oxygen levels will decline, causing death of aerobic benthic organisms

Pollutants

Storm water runoff may contain petrochemical residues, spilled industrial chemicals, paints and solvents, pesticides used on lawns and gardens, etc. Other forms of pollution may occur due to seepage from septic tanks and discharge of sewage from boats. Dangerous substances may also be released as by products from industrial processes, such as desalination. All of these materials may be toxic to plants and animals in the estuary and results in a loss of overall productivity or selective loss or decline of particular species.

Sources of Water Quality Degradation

The Watershed Action Plan (FDEP, 1998) identified a number of potential water quality issues within the Loxahatchee Basin. Possible sources of water quality degradation included: highly colored water from natural areas; contamination from septic tanks; agricultural and urban storm water runoff containing petrochemical residues, suspended solids, pesticides, nutrients and fecal coliform bacteria; chemical contamination from a regional landfill; discharge of effluent from a reverse osmosis water treatment plant; and low levels of DO due to ground water influx and loading of organic materials.

State Listing of Impaired Waters

A more detailed examination of water quality issues in the basin was conducted by the Florida Department of Environmental Protection (FDEP) in conjunction with their ongoing efforts to identify waters that are degraded and develop Total Maximum Daily Load (TMDL) criteria for waters throughout the state. The St. Lucie and Loxahatchee Basin Status Report, (FDEP, 2001), initiated Phase 1 of the five-phase TMDL process in the Loxahatchee Basin. Most of the information presented in the Basin Status Report was generated from the biennial Water Quality Assessment Report that is developed by FDEP for submittal to the United States Environmental Protection Agency (USEPA) under section 305(b) of the Clean Water Act (FDEP, 1996). **Table 5** below provides a summary of the recent re-assessment of water quality in the estuarine segments of the Loxahatchee watershed (**Figures 2 and 6**).

Table 5. Quality Assessment of Water Body Segments of the Loxahatchee Estuary (FDEP 2001)

Water Segment Name	Water Body Type	Class	1998 303(D) List Parameters	Parameters Potentially Impaired Per IWR	Integrated Assessment Category	Comments
Jonathan Dickinson	Estuary	3M		DO	3c planning list	Need to determine causative pollutant for DO violation
Loxahatchee River (estuary)	Estuary	3M			2 meets some uses	
NW Fork Loxahatchee (estuary)	Estuary	3M	DO, nutrients		2 meets some uses	
SW Fork Loxahatchee (estuary)	Estuary	3M	DO, nutrients, coliform		2 meets some uses	
Jupiter Inlet	Estuary	3M			2 meets some uses	

Classes - Class III – Recreation, propagation and maintenance for a healthy, well-balanced population of fish and wildlife. M=marine,
Integrated Assessment Category

Category 2 – Data are available to assess if some beneficial uses are being met, while insufficient data are available to assess whether all beneficial uses are being met.

Category 3c – Enough data are available to meet the requirements for the Planning List in Rule 62-303 and the water body is potentially impaired for one or more designated uses.

The assessment was based on the Impaired Water Rule criteria (IWR, Chapter 62-303, Florida Administrative Code) using established criteria and methodology to determine the extent that water bodies are impaired in their ability to meet their intended use. Estuary segments of the

Loxahatchee River are Class III water bodies that are used for recreation and for propagation and maintenance of healthy, well-balanced fish and wildlife populations. The original (1998) 303(d) list was based primarily on the state's 1996 305(b) Water Quality Assessment Report (FDEP, 1996). The report identified specific parameters in each water segment that did not meet the state water quality standards as identified in rules 62-302.500 and 62-302.530 F.A.C. In the estuarine areas of the system, the Northwest Fork did not meet DO and nutrient standards and the Southwest Fork did not meet DO, nutrient and coliform standards.

The projected year for developing the TMDL for these water segments within the Loxahatchee Basin, as identified in the 1998 303(d) list, is 2010. However, interested stakeholders can take earlier steps to establish technology-based effluent limitations or other pollution control programs for the constituents of concern. Pursuant to section 403.067 Florida Statutes (F.S.), if steps are taken to attain water quality standards for impaired water bodies by the next time the 303(d) list is due to be submitted to the USEPA, then those water bodies do not need to be placed on the verified list.

The data for the verified list of impaired waters is tentatively due by March/April 2003 and includes any data collected from 1991–2001. The draft verified list is currently expected to be published at the end of June 2003, public workshops will be held throughout the state in July, and the verified list would be adopted by the FDEP Secretary at the end of August 2003. October 1, 2003, is the deadline for the publication of the Group 2 verified list of impaired waters in the Florida Administrative Weekly and submittal to the USEPA.

Water Quality Initiatives

A number of projects are underway in the Loxahatchee River watershed that are jointly funded by local interests, the state and SFWMD and are designed to improve water quality conditions in the watershed and the estuary. In addition, the Loxahatchee Restoration Initiative, between the FDEP and SFWMD, will not only consider the additional quantities of water needed for the Loxahatchee River and Estuary, but also the quality, especially for major constituents of concern, including DO, nutrients and coliform bacteria. The SFWMD is also carefully reviewing Environmental Resource Permit (ERP) applications for projects in this watershed for opportunities to improve the quality of runoff generated from these projects. A new 3-dimensional hydrodynamics/salinity model is also being developed that will incorporate water quality data. Additional flow stations are also being installed in the river. The Loxahatchee River Environmental Control District will collect additional water quality samples bimonthly to provide improved estimates of the loads and DO levels associated with specific flows and salinity values in the Loxahatchee River and Estuary.

ADJACENT COASTAL WATERS

The Coastal Subbasin encompasses approximately 34 square miles and stretches from Hobe Sound south to Juno Beach, a distance of 20 miles (**Figure 5).** This area includes the Jupiter Inlet and adjacent offshore waters and the ICW, which is also known as the Indian River

Lagoon north of the Jupiter Inlet and Lake Worth Creek south of the Jupiter Inlet. The movement of water in this sub-basin is predominantly influenced by tides, with lesser impacts from wind and drainage of upland areas. On incoming tides, most of the seawater enters the inlet and moves westward into the estuary and northward into the Indian River section of the ICW. A substantially smaller interface is created between the incoming tides and the portion of Lake Worth Creek between the inlet and Juno Beach. Under normal conditions, water is discharged out the inlet from the estuary on an ebb tide.

Lands adjacent to these areas include both developed land and natural landscapes. A major defining characteristic of the Coastal Sub-basin is the Atlantic Coastal Ridge. Water drains quickly in the area due to the fine sands. Storm water can have an impact on the area by leaching fertilizer and pesticide to the ground water. Ground water beneath much of the Coastal Sub-basin consists of deep saline areas overlain by thin freshwater lenses. The volume of freshwater available for withdrawal is very limited.

The urbanized corridor of U.S. Highway 1 is a major feature of the watershed in Palm Beach and Martin Counties. Storm water contributions come from a number of developments. Some have canal systems that open into the ICW, others pipe runoff into the surface waters. Publicly-held conservation lands are located at both ends of the sub-basin, in Juno Beach and along the Jupiter oceanfront. The basin includes a small portion JDSP and Hobe Sound National Wildlife Refuge.

WATERSHED FEATURES AND ALTERATIONS

During the past 100 years, the natural hydrologic regime of this watershed has been altered by drainage activities associated with urban and agricultural development. Historically the watershed was defined by the natural landforms of the region. The Northwest Fork of the Loxahatchee River drained the majority of the Loxahatchee Basin. The headwaters of the river originated in the marshes of the Loxahatchee and Hungryland sloughs. As water levels rose during the rainy season, due to the area’s flat topography, freshwater drained off gradually as shallow sheet flow during the dry season (Breedlove, 1982). Today much of the area has been transected by canals, levees and drainage ditches. The area's water table has been lowered and lands drain more rapidly because of these activities. Construction of the C-18 for drainage and flood protection has diverted much of this surface flow to the Southwest Fork of the river (Breedlove, 1982). McPherson and Sabanskas (1980) reported that the Loxahatchee River basin historically covered about 270 square miles defined solely by its topography. Today the basin covers about 210 square miles and is defined by its topography and manmade features.

In addition to opening of the Jupiter inlet, several other major changes also occurred within the watershed. The first report of a basin drainage project was in 1928 when a small agricultural ditch was constructed to divert water from the Loxahatchee Marsh to the Southwest Fork of the Loxahatchee River. This project was further expanded in 1957–1958 when the USACE constructed the C-18 Canal to provide increased flood protection for the area (**Figure 7).** Construction of C-18 essentially drained a large portion of the Loxahatchee Slough, a natural wetland area at the headwaters of the Northwest Fork, and redirected water that historically flowed to the Northwest Fork to the Southwest Fork where it could be discharged to tide through Structure 46 (S-46). The C-18 currently drains over one-half of the Loxahatchee Basin.

A number of other hydrologic alterations occurred directly on the Northwest Fork and its tributaries. During the 1930s, two local families constructed the Masten and Lainhart Dams **(Figure 7**) on the upper Northwest Fork to slow down the flow of freshwater between Indiantown Road (SR 706) and Trapper Nelson's settlement. Sometime between 1940 and 1953, Hobe Grove Ditch and the Federation Canal were dredged to drain low-lying areas for citrus groves in the late 1960s. Sod farming has been a more recent agricultural change. The Chinese vegetable farm was operating years before sod farming was undertaken. Flows to the Northwest Fork via Kitching Creek were further reduced during the 1940s by the construction of Bridge Road (County Road 708) and Jenkin's Ditch and by the introduction of citrus groves and sod farming. By the 1970s, much of the Loxahatchee Basin had been drained for residential or agricultural uses.

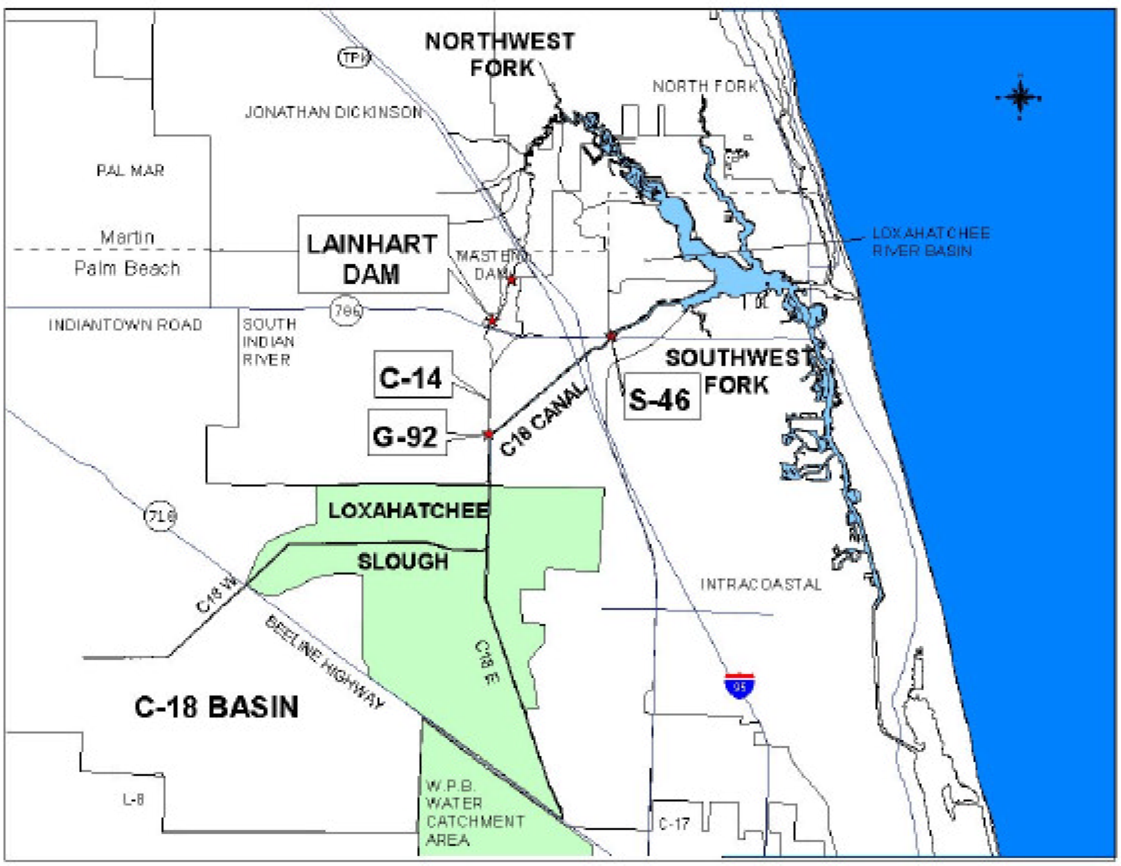


Figure 7. Major Features that Influence Drainage in the Loxahatchee River Basin

In response to public concerns that the C-18 diversion was detrimental to the river, a SFWMD structure known as G-92 was constructed to reestablish the connection between the Loxahatchee Slough and the Northwest Fork (**Figure 7).** Originally a small culvert, this structure was enlarged to convey up to 130 cfs in 1975. In 1987, G-92 was replaced by a gated control structure capable of passing up to 400 cfs in either direction. This structure is operated via remote telemetry under a joint agreement with the South Indian River Water Control District (SIRWCD) to permit conveyance of environmental flows to the Northwest Fork. G-92 also functions to convey excess water from the SIRWCD into the C-18 during extreme storm events (FDEP and SFWMD 2000). The District has an agreement to operate G-92 to provide 50 cfs of flow to the river whenever water is available (see **Appendix L**).

During the severe drought of 1980–1981, the operation of the S-46 structure was modified to provide storage of water in the canal to reduce the amount of freshwater lost to tide. The S-46 structure allows discharge to the Southwest Fork only when water levels are greater than 15 feet above mean sea level.

An extensive network of regional drainage canals and dikes has been constructed and connected to the C-18 system as it flows north out of the Loxahatchee Slough. The C-14, which parallels the C-18, was constructed by the SIRWCD to re-divert water from the C-18 back to the Northwest Fork via G-92 (**Figure 7**).

The C-14 terminates where the river's natural meandering pattern begins about one-half mile south of Indiantown Road (SR 706) as shown in **Figure 7**. The C-14 receives inflow from a series of smaller canals and drainage ditches. Construction of C-14 further enhanced the amount of water that can be delivered to the Northwest Fork from G-92 (Russell and McPherson, 1984).

Several projects are in planning stages or underway to restore sheet flow and enhance wetlands in Kitching Creek and Cypress Creek Sub-basins and Loxahatchee Slough. Other current projects involve storing runoff in treatment areas for later release to the Northwest Fork during low flow periods. These projects are discussed further in **Chapter 6**.

Surface Water Hydrology

Water is the most essential component of the Loxahatchee River ecosystem. Clean fresh water of sufficient quantity and appropriate periodicity is essential to maintain the area's scenic qualities and diverse native plant communities and wildlife populations. Human alterations to the river's natural drainage patterns have reduced the quantity and quality of water in the river, and these changes have contributed to corresponding declines in the river's natural and scenic qualities (FDEP and SFWMD 2000).

A report prepared by the USGS (Rodis, 1973) concluded that the primary cause of environmental problems facing the river was the upstream movement of saltwater, which, in turn, resulted in changes to the flora and fauna in JDSP, and other portions of the river. In this study, based on salinity, freshwater flow data, and the drainage and development conditions that existed at that time, it was concluded that a minimum continuous flow of 23,000 gallons per minute (50 cfs) was required across the Lainhart Dam. This minimum continuous flow would retard further upstream movement of saltwater into the Northwest Fork.

Much of the reduction in flow observed by the USGS has been attributed to the diversion of historic Northwest Fork flows due to construction of the C-18. The C-18 drainage system is the most prominent feature in the Loxahatchee River basin (**Figure 7).** The C-18 was constructed in 1958 as part of the Central and South Florida Flood Control Project to improve drainage and flood protection for adjacent agricultural, residential, and industrial land as well as the J.W. Corbett Wildlife Management Area. This system drains a 106 square-mile area (more than 50 percent of the river basin), and empties into the Southwest Fork through control structure S-46. The C-18 is of particular significance because it: (a) drained the Loxahatchee Slough; (b) redirected water that historically flowed from the slough to the Northwest Fork to the Southwest Fork; and (c) allowed agricultural and residential development to occur in the basin, requiring maintenance of lower water levels and a consequent loss of water storage capacity. The other major drainage system in the Loxahatchee River basin is the C-14 (**Figure 7)** maintained by the South Indian River Water Control District (SIRWCD). It lies west of C-18 in an area known as Jupiter Farms. This area has been subdivided and sold as residential tracts ranging in size from one to five acres. Drainage occurs through a series of seven east-west collector canals into the C-14, and a North-South canal administered by SIRWCD. The C-14 discharges directly into the Northwest Fork, just south of the bridge at Indiantown Road.

Water from the Loxahatchee Slough flows north toward the Loxahatchee River via the C-14, the G-92 structure and the Lainhart Dam as shown in **Figure 7** providing the primary source of flow to the Northwest Fork. On average, the Lainhart Dam accounts for 51–56 percent of the total discharge to the Northwest Fork during the wet and dry seasons (see **Table 23, Chapter 5**). On a monthly basis, however, discharge from this source can range from as low as 28 percent to as high as 72 percent of the total discharge (Russell and McPherson, 1984).

The operation schedule for G-92 structure is important to the river management program because it determines water flow to the Northwest Fork. Water is discharged from C-18 through the diversion structure depending on the relationship between water levels in C-18 and the Northwest Fork at Indiantown Road. Water is diverted to C-14 when (a) flows in C-14 fall below 50 cfs; and (b) when levels in C-18 exceed 12.5 feet above sea level (normal canal stage is 14.5 feet). Under this operational schedule discharges to the Northwest Fork have increased significantly since the operation of G-92 began. This is partially because of: (a) higher rainfall amounts; (b) C-18 has been maintained at higher levels; and (c) water levels at Indiantown Road have been improved due to the reconstruction of Lainhart and Masten Dams, (two small weirs located about 0.1 mile and 1.2 miles respectively, downstream of Indiantown Road). Erosion of these weirs, along with canal construction in the basin, probably increased historic drainage of the area, thus contributing to increased discharges into the river and subsequent over-drainage and potential loss of base flow. In addition to flows coming in from upstream via the C-14, the segment of the Northwest Fork between Indiantown Road and the Florida Turnpike/I-95 receives an average of nearly 12 percent of its total flow from groundwater inflow and several small, unnamed tributaries within this reach.

Since the C-18 has very little capacity to store water for a prolonged controlled discharge, supplemental discharges may be terminated during extended dry periods. Since the installation of G-92, flows to the Northwest Fork have increased considerably, partially due to improved conveyance capacity and improved operations, and partly due to increased rainfall in the watershed during the 1990s. These improved flows, however, have not been sufficient to completely achieve a sustained flow of 50 cfs (a stage of 10.9 feet at the Lainhart dam), which is desired to preserve the freshwater character of the river. Restoration of more historic water levels in the Loxahatchee Slough, which could then sustain longer base flow discharges to the Northwest Fork during drought, is the next step toward achieving this objective. In addition, Palm Beach County has acquired 10,389 acres within the Loxahatchee Slough as a component of the Palm Beach County's Environmentally Sensitive Lands Acquisition Program. A plan for hydrologic restoration of the Slough and flow enhancement to the Northwest Fork is currently being developed (SFWMD 2002). Palm Beach County also has a wetlands restoration project underway in Riverbend Park, located downstream from the slough, which may provide additional flow attenuation and water quality benefits to the Northwest Fork.

Cypress Creek **(Figure 2**) is another significant source of surface water to the Northwest Fork, particularly during periods of low flows. This tributary enters the river from the west, just downstream from the Trapper Nelson Interpretive Site in JDSP. Discharges from Cypress Creek are normally less than those provided by the Lainhart Dam. Cypress Creek provides on average from 26–32 percent of the total flow discharged to the Northwest Fork (**Table 23, Chapter 5**)

Cypress Creek is an outlet for an extensive network of agricultural canals, draining an area of about 29,000 acres, maintained by the Hobe-St. Lucie Conservancy District. Flows from Cypress Creek to the Northwest Fork are controlled by a structure that is operated by a local drainage district. The first portion of the Cypress Creek subbasin is composed of undeveloped wet prairie. These undeveloped areas are experiencing reductions in water levels due to canal construction, but still act as an important freshwater reservoir for Cypress Creek and the Northwest Fork. In 1995, Palm Beach County acquired 367 acres near Cypress Creek as part of their Environmentally Sensitive Lands program. This acquisition, and more importantly the Pal-Mar wetlands acquisition, with modification of agricultural practices, will result in some improvements to the subbasin hydrology.

Hobe Groves Ditch (canal) drains a large agricultural area (10,700 acres) east of the Florida Turnpike and enters the river at approximately River Mile 9.0. The “ditch” has a water control structure that is operated by local groves. Discharges from this canal averages less than five percent of the freshwater flow into the Northwest Fork **(Table 23, Chapter 5).**

Kitching Creek originates in an area of scattered ponds and marshes both north of and within, JDSP. Kitching Creek average between 11 and 13 percent of the total flows delivered to the Northwest Fork **(Table 23, Chapter 5).** Its drainage basin is the least developed of all the major tributaries of the Northwest Fork and allows for a high degree of water retention.

Surface Water and Ground Water Relationships

Major Aquifer Systems

The geologic formations underlying the area of the Loxahatchee River form two aquifers separated by confining beds. The two major aquifers are the shallow, upper 200 feet of sand, (non-artesian) Surficial aquifer and the Floridan aquifer, which are more than 1,000 feet deep (**Table 6).** The Surficial aquifer is composed of permeable Pamlico sand, Anastasia limestone, shell beds and Caloosahatchee marl. Although the shallow Surficial aquifer represents the primary source of potable water for the watershed, its water-bearing qualities vary widely throughout the area. Most of the recharge for the Surficial aquifer is supplied by local rainfall. The bottom of the shallow aquifer is generally about 180 feet below the land surface (Lukasiewicz and Smith, 1996; SFWMD, 1998).

Table 6. Generalized Hydrogeology of the Loxahatchee Watershed

Hydrogeologic System	Hydrogeologic Unit	Aquifer Thickness (Feet)	Water Resource Potential
Surficial Aquifer System	Units not distinct	100-200	Primary source of potable water
Floridan Aquifer System	Upper Hawthorn Confining Zone	500	May only be used for potable drinking water with desalinization.
	Upper Floridan Aquifer		

Source: (Lukasiewicz and Smith, 1996; SFWMD; 1998)

The Floridan aquifer, is separated from the Surficial by several hundred feet of relatively impermeable clay, and extends to depths of about 1,500 feet. This confined aquifer contains water under sufficient pressure to cause it to flow to the surface. In the Loxahatchee River area, the aquifer is composed of limestone of the Hawthorn, Tampa, Suwannee, Ocala and Avon Park formations, ranging in age from 30 to 60 million years. This aquifer is hydrologically isolated from the Surficial aquifer, and is highly mineralized and contains moderately high salt concentrations. It can be used for potable drinking water supply only with desalinization treatment. The principal recharge area for the Floridan aquifer is located in Polk and Pasco Counties in central Florida. These two aquifers supply all of the drinking water for this watershed (FDEP, 1998).

Relationship between Ground Water and Surface Water Resources

The surficial aquifer system in northern Palm Beach and southern Martin Counties interacts directly with surface water in streams, rivers, canals, ponds, lakes and wetlands. The presence of a manmade (e.g. canals) or natural (stream or river) channel provides a conduit by which water flows downhill, generally towards the ocean. As water levels decline in the channel, water flows into the channel from adjacent surface water storage (ponds, lakes or wetlands) or by ground water seepage. Rainfall provides the major source of “new” freshwater that fills the surface water bodies and channels and recharges the shallow aquifer system.

In the historic Loxahatchee River watershed, an extensive network of wetlands, lakes and seasonal ponds formed a vast reservoir of freshwater that was refilled each year during the rainy season. This water flowed into the network of tributaries that fed the Loxahatchee River and was discharged to tide at the river mouth. As water levels in the wetlands, tributaries and river declined during the dry season, water continued to enter the natural channels by ground water seepage from the surficial aquifer, so that flow in the river was maintained, probably year-round, except during extremely dry conditions.

Today, canals and ditches that have drained many of the wetland areas and seasonal ponds to allow agricultural and residential development have intersected much of the watershed. Rain that falls in these areas during wet periods is rapidly shunted to the major canals and river and does not accumulate in wetlands or the shallow aquifer. Therefore, the river and canals are discharging more water during the wet season. During the dry season, much less surface water and ground water is available to maintain river flow.

The amount of water that enters the Loxahatchee River system is thus divided among direct rainfall, surface water flow and ground water seepage. The SFWMD has reviewed available information and attempted to analyze all three of these components. Some previous studies provided data and estimates of rainfall and surface water flows from major tributaries. By measuring total river flow at the mouth, it is possible to estimate flow from sources other than rainfall and surface flow. These ”other” flows are generally attributed to ground water seepage.

Mathematical models were developed and applied by the District to determine the interaction between ground water and surface water resources in the Palm Beach County portion of the Loxahatchee River watershed. Use of these models provides a convenient way to summarize existing information about this system and to make predictions concerning the amount and timing of river discharges. Details of historical flows and the interactive surface water-ground water modeling effort are provided in **Chapters 4 and 5** and **Appendix I**.

Soils

Soils of the Atlantic Coastal Ridge and the Eastern Flatlands within the Jonathan Dickinson/Hobe Sound sub-basin consist of old dunes and flatlands. The dunes, dune ridges and other minor dune patterns that are present near the west side of U.S. Highway 1 run north to south and consist of fine, white sand of the Paola-St. Lucie association. The flatlands contain flat terraces with poorly drained sandy soils that are interspersed with shallow depressions. Soils in the Coastal sub-basin are generally those associated with Paola-St. Lucie sands and are well-drained and highly permeable. In tidal zones, thin muck overlays permeable sands (FDEP 1998; Zahina et al. 2001a).

The northeastern portion of the Estuary sub-basin generally has well drained sands of the St. Lucie-Urban-Paola association. Well-drained sands of the St. Lucie-Urban-Paola association and Pomello and Basinger sands make up the area between the North Fork and the C-18, Southwest Fork drainage Channel. The area south of the estuary and C-18, Southwest Fork Drainage Channel consists mostly of nearly flat, poorly drained sands of the Wabasso-Riviera soils (FDEP 1998; Zahina et al. 2001a).

Wetland areas of the watershed in the C-18/Corbett sub-basin contain soils that are generally of the Riviera sand series, consisting of poorly drained sandy soils with loamy subsoil. In the eastern or "Loxahatchee Slough" area some of the soils have a thin layer of muck at the surface. Soils in the Cypress/Pal-Mar sub-basin are mostly of the Wabasso, Riviera and Pineda series: poorly drained and sandy to a depth of 20 to 40 inches (FDEP 1998; Zahina et al. 2001a).

The Groves sub-basin contains predominantly Hobe fine sand and Nettles sand in the river corridor and immediately west. The groves themselves consist mostly of Wabasso-Riviera sands with Pineda-Riviera soils along the northwestern boundary. The western and southwestern areas are predominately Pineda-Riviera-Boca soils. These soils are poorly drained and sandy to a depth of 20 to 40 inches. Soils in the Wild and Scenic/Jupiter Farm sub-basin are predominantly poorly drained sands, such as those within the Riviera and Wabasso Series and also include Pineda and Oldsman (FDEP 1998; Zahina et al. 2001a).

Land Use

Much of the Loxahatchee River watershed remains undeveloped. Wetlands comprise a large portion of the river's upper watershed and total almost one-half of the drainage basin's 200 square miles. Urban areas and areas committed to urban uses make up one-quarter of the basin. The large agricultural and forested upland areas in the northern portion of the basin collectively comprise another one-quarter of the basin **(Figure 8). Tables 7** and **8** provide a detailed breakdown of the major land use categories (agricultural, range land, residential, industrial, commercial, undeveloped, transportation, conservation, institutional and other) for each of the seven major drainage basins located within the watershed.

Land in the river's watershed has most typically been converted to urban uses. The extreme southeastern section of the basin along the eastern edge of Loxahatchee Slough is one of the fastest developing areas in the basin. Another major area of land development is located in the central portions of the basin, both east and west of C-18. Jupiter Farms, located west of the Loxahatchee River and south of Indiantown Road, is one example of the type of land development activity that has occurred in this portion of the basin. This 9,000-acre subdivision was platted in the 1920s and consists of parcels generally ranging in size from one to five acres. When completed, the project will contain over 4,600 dwelling units and a population of more than 11,000 residents. Since the area was subdivided before current water quality regulations were in effect, modern provisions for the retention of surface water runoff were not included. A third area undergoing urbanization is located north of Indiantown Road, bordered on the west, northwest and east by the Northwest Fork. Existing land use activity is predominately agricultural, with most of the land in pasture or pine flatwoods. Major residential developments and golf courses have been proposed or approved in this area.

Land use patterns in the immediate vicinity of the Northwest Fork are similar to those throughout the rest of the drainage basin. Wetlands are characterized primarily by extensive areas of wet prairie, freshwater swamp and mangroves. Agriculture accounts for approximately 23 percent of the land use in the vicinity of the Northwest Fork. Croplands, consisting mainly of vegetable farms were, until quite recently, located along either side of the middle segment of the

river. In most cases, these areas are separated from the river corridor by a band of pine and scrubby flatwoods. Orchards and groves predominate in the northwestern sections of the river area. Several small citrus groves are located in the Indiantown Road area within approximately 250 feet of the river. Improved pasture comprises a portion of the agricultural land cover east of the Florida Turnpike/I-95 corridors. Areas that are committed to urban uses are scattered throughout the eastern and southern portions of the mapped area, primarily in the areas south of JDSP and south of Indiantown Road. A small community shopping center is located 0.2 miles west of the river on Indiantown Road (FDEP and SFWMD 2000).

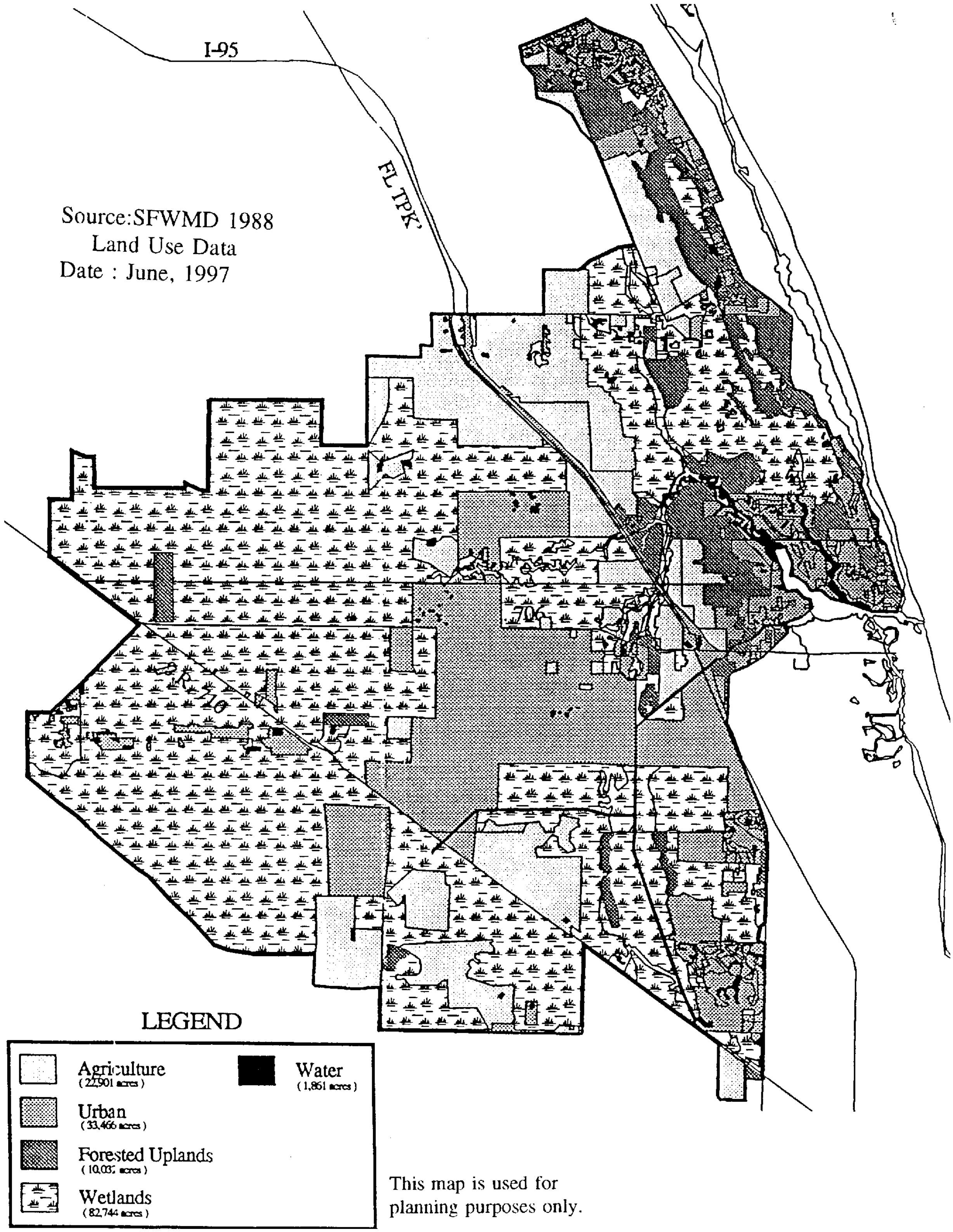


Figure 8. Current Generalized Land Use/Land Cover in the Loxhatchee Watershed (from FDEP and SFWMD 2000).

Table 7. Acreage Percentage by Land Use for Subbasins within the Loxahatchee River Watershed

		Land Use Categories											
sb	**Subbasin Name**	**Water**	**Agriculture**	**Range Land**	**Residential**	**Recreational**	**Industrial**	**Commercial**	**Undeveloped**	**Transportation**	**Conservation**	**Institutional**	**Other Urban**
1	Jonathan Dickinson/ Hobe Sound		10.9%	4.8%	3.8%	1.6%	0.3%	0.0%	37.6%		41.0%		
2	Coastal		2.6%		30.4%	7.6%	2.3%	4.1%	50.2%	2.8%			
3	The Estuary	11.1%	4.8%		56.0%	5.5%	2.4%	1.2%	16.6%	1.8%		0.6%	
4	C-18/Corbett	2.4%	8.0%		3.5%	2.1%	3.8%	0.1%	78.0%	1.8%			
5	Cypress/Palmar	2.2%	12.1%		3.7%	1.2%			79.5%	0.2%			1.1%
6	The Groves	1.2%	59.5%		0.5%	0.5%			34.8%	3.0%			0.5%
7	Wild & Scenic/Jupiter Farms	2.1%	5.4%		56.8%	1.3%	3.3%	0.1%	29.8%	0.6%			0.6%

sb = Subbasin Number Source: SFWMD 1995 GIS Land Use Database

Table 8. Acreage by land use for subbasins within the Loxahatchee River watershed

		Land Use Categories												
sb	**Subbasin Name**	**Water**	**Agriculture**	**Range Land**	**Residential**	**Recreational**	**Industrial**	**Commercial**	**Undeveloped**	**Transportation**	**Conservation**	**Institutional**	**Other Urban**	**Total Acres**
1	Jonathan Dickinson/ Hobe Sound		2,509	1,105	875	368	69		8,656		9,439			23,021
2	Coastal		572		6,692	1,673	506	902	11,050	616				22,012
3	The Estuary	1,524	659		7,690	755	330	165	2,280	247		82		13,732
4	C-18/Corbett	1,540	5,132		2,245	1,347	2,438	64	50,039	1,155				64,153
5	Cypress/Pal-Mar	652	3,587		1,097	356			23,569	59			326	29,647
6	The Groves *	129	6,382		54	54			3,733	322			54	10,726
7	Wild & Scenic/ Jupiter Farms *	316	813		8,549	196	497	15	4,485	90			90	15,051
	Total	4,161	19,661	1,105	27,201	4,749	3,831	1,146	103,812	2,490	9,439	82	470	178,342

sb = Subbasin Number Source: SFWMD 1995 GIS Land Use Database

* Ongoing boundary studies may change the total size of the basins which would result in slight changes to the land use areas.

Water Supply

How Water is Allocated and Used:

The withdrawal of surface or ground water for consumptive use is regulated through permits issued by the SFWMD. All sources of supply are regulated except seawater (with total dissolved solids greater than 18,000 mg/l), reclaimed water and water used for domestic self-supply and fire-fighting. A consumptive use permit is not a permanent right to water but is issued with a finite duration. At the end of the permit tenure the user may apply for a renewal. Renewals are treated as initial applications (except in cases of competing applications) and reviewed under the rules in place at the time of the renewal application.

In order for a proposed use to qualify for a consumptive use permit the applicant must demonstrate that the use is reasonable and beneficial, will not interfere with existing legal users and is in the public interest (Chapter 373 F.S.). The SFWMD has rules which outline how such reasonable assurance shall be provided. These assurances must be met for all consumptive use classes including public water supply, irrigation, dewatering, industrial etc. The reasonable assurance must cover hydrologic conditions up to and including moderate drought conditions known as the level of certainty. In South Florida this level of certainty is being established by rule as a 1-in-10 year drought condition.

The amount of water allocated in a permit is sufficient to meet the reasonable demands of the use over the life of the permit up to the level of certainty (1 in 10 year drought). For most use classes the reasonable volume of water needed is less than the allocation during normal to wet conditions and increases as droughts become more severe. This trend is most noticeable with irrigation uses. In some cases the need for water increases over time as the project grows (public water supply and some agricultural projects).

Irrigation allocations are currently determined using the modified Blaney-Criddle algorithm to calculate supplemental irrigation based on several factors including evapotranspiration (ET), crop type, rainfall, time of year and soil type. This algorithm was developed by the University of Florida Institute of Food and Agricultural Sciences (IFAS) and has been used in consumptive use permitting since the mid 1980s. The algorithm calculates the plant supplemental irrigation demand that occurs during a maximum month (under the 1 in 10 year drought condition) and on an average annual basis. Recent studies of actual water use and plant transpiration indicate that the Blaney-Criddle algorithm overestimates annual average plant demand but is accurate for the maximum month during 1-in-10 drought conditions.

Public water supply allocations are based on population and historic per capita use rate. The use of water generally varies seasonally as a function of population (including tourism) and rainfall patterns. The per capita use rate is calculated by dividing the volume of untreated water used by the permanent population served. The allocation is based on the projected population for the last year of the permit life multiplied by the per capita use rate adjusted for water conservation. The per capita rates can vary widely if the service area uses potable water for irrigation or has a significant commercial/industrial demand. In situations where saline water is used for drinking water supply, the per capita use is about 15–20 percent higher due to the treatment losses associated with the desalinization process. Per capita use rates average 203 gallons per capita per day (gpcd) in the north Palm Beach County area.

Once the reasonable needs for water are defined, the applicant must provide reasonable assurance that the water resources (wetland, saltwater intrusion, MFLs, etc.) and existing legal users are not harmed during a 1-in-10 drought condition. This is generally done by evaluating the area of impact of the proposed use, assuming that the maximum monthly demand is sustained day and night for 90 days without rainfall. This combination significantly overstates the impact of the proposed use under all but excessive drought conditions. As a result, the impacts of the actual use are, in most cases, less than what is evaluated in order to obtain a permit. The thresholds for *no harm* are contained in District permit criteria.

Computer ground water models and field monitoring data are used to provide reasonable assurances that the permit criteria will be met. In cases where the criteria cannot be met, the applicant may propose alternatives that mitigate the impact of the proposed withdrawal. Examples of mitigation include relocating the point of withdrawal, reducing the demand for water from the source by augmenting the need for water from other sources, such as reclaimed or potable water, or by developing different sources of supply, such as the Floridan Aquifer System (FAS). In the event that reasonable assurances cannot be provided, the applicant may withdraw the application or the District will deny the application.

Permits may also be conditioned to include monitoring of use and impacts of the withdrawal. All individual water use permits issued since 1993 are required to report the amount of water used. In addition, projects that have the potential to impact wetlands, alter the position of a saline/freshwater interface, produce a plume of pollutants or affect other existing legal users, are required to monitor water levels and or quality as appropriate.

Overview of Consumptive Uses within the Watershed:

As of May 2002, the combined annual allocation for all individual water use permits within the watershed was 37,672 million gallons per year (an overall average of about 100 million gallons per day). A more detailed analysis of permitted water uses is provided in **Appendix O.** Locations of the 404 permitted wells and 232 surface water pumps are shown on **Figure 9.**

Figure 10-A shows the relative degree of contribution of water supply allocations by source type within the basin. Ground water provides for the majority of the demands followed by surface water, the FAS and reclaimed water. Reclaimed water and the saline water of the FAS are considered alternative sources of supply. Together these alternative sources comprise 22 percent of the water used within the watershed. The volume of reclaimed water represents 100 percent of the dry season treated wastewater flows generated from the public water supply. The reclaimed water is recycled into the basin as irrigation water during the dry season. During the wet season, when demands for irrigation water drop below the rate of reclaimed water production, the unused portion of reclaimed water is stored for later use or disposed of by deep well injection. The volume of reclaimed water in the watershed is expected to increase in proportion to growth in demands for potable water. For those utilities that use the FAS as a source for potable water (Town of Jupiter and Village of Tequesta), the proportion of reclaimed water recovered from the FAS represents an increase in supply to the surficial system.

Figure 10-B shows the relative degree of water allocation by million gallons per year (mgy), by use class in the watershed. Public water supply has the largest allocation (63% or 23,638 mgy) followed by agriculture (18% or 6,943 mgy), golf course irrigation (8% or 2,973 mgy), industrial use (6% or 2348 mgy), and landscape irrigation (5% or 1770 mgy).

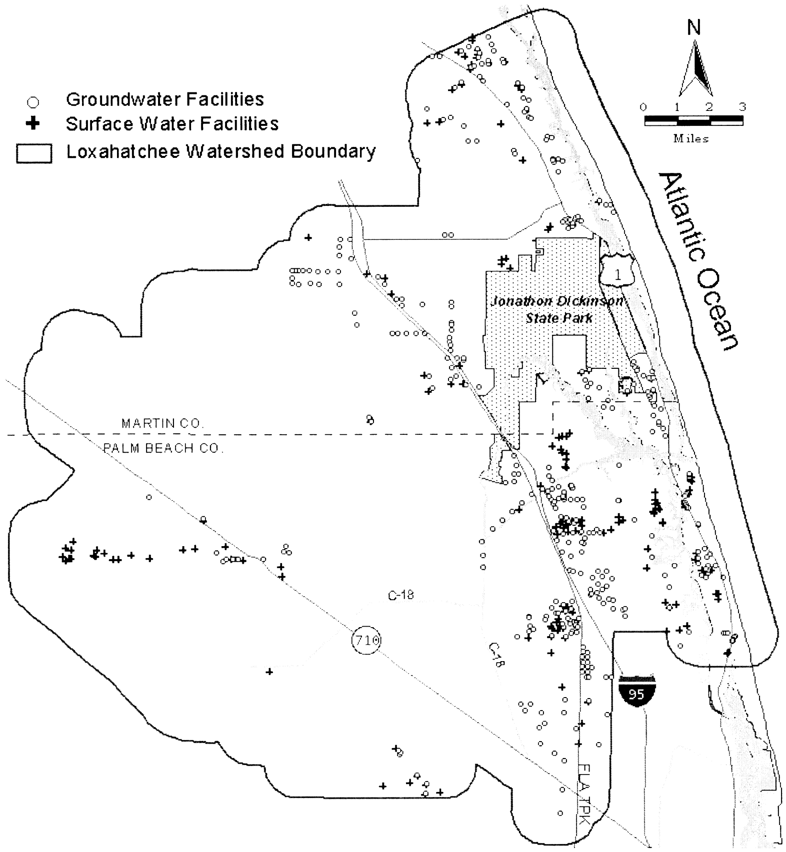


Figure 9. Locations of Permitted (individual permits) Withdrawal Facilities within the Loxahatchee River Watershed Area, May 2002.

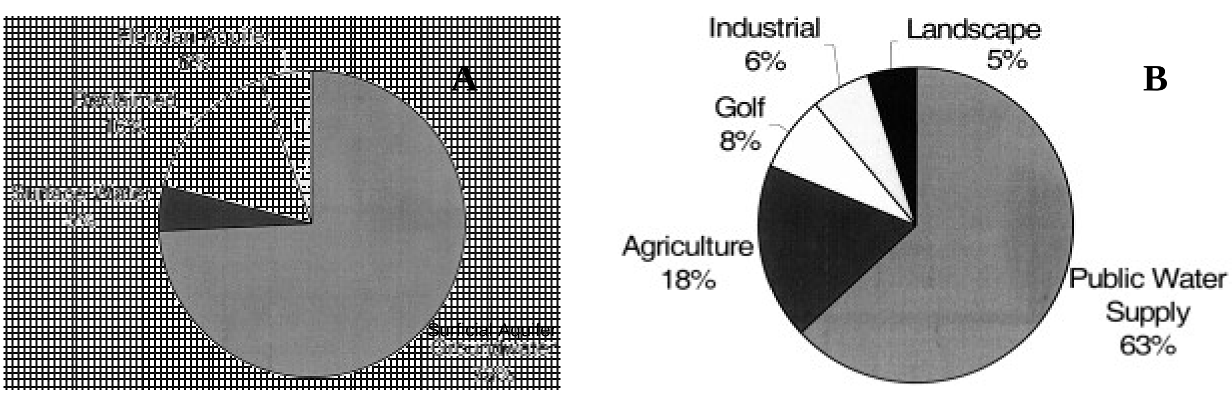


Figure 10. Water Use in the Loxahatchee River Watershed from Different Sources (A) and for Different Uses (B) based on SFWMD Consumptive Permit Allocations as of May 2002.

Additional details are provided in **Appendix O**. It is important to note that the actual uses on any given day are usually considerably less than the permitted allocations, except during periods of severe and sustained drought. For instance, all irrigation allocations are geared to provide sufficient water to survive a moderate drought where actual use is dependent on rainfall. When rainfall drops off, the use increases and approaches the allocation. However during normal or wet conditions, the use is lower than the allocation. Also, demands for water do not coincide for all users. The peak demand for irrigation of citrus occurs in a different month than the peak demand for turf grass. The amount of acreage planted (and the corresponding amount of water used) during any given year for growing vegetables are market driven. If the market is down, crops are not planted and water use is less than the allocation. Only when the market is good and there is a moderate drought would the actual use approach the allocation for vegetables.

In some cases, the allocated demands are not achieved until the end of the permit. Public water supply allocations are based on the estimated demand at the end of the permit duration. For example, comparison of actual public water supply pumpage to permit allocations within the watershed during 2000 (the last full year prior to the water shortage), shows that actual use was 40–90 percent of the permitted allocation. However, it should be noted that due to improvements in the accuracy of the methods for estimating future public water supply demands, combined with shorter duration permits, the gap between actual use and permitted use is smaller.

Water Quality

During the last 25 years, the surface waters of the Jupiter Inlet-Loxahatchee River have been extensively sampled and analyzed for water quality. In the 1970s and 1980s, the United States Geological Survey provided a water quality monitoring presence from the federal perspective. The FDEP and the SFWMD each sponsored monitoring programs from the state and regional perspective. On the county and local level, the Palm Beach County Health Department, Palm Beach County Department of Environmental Resources Management and the Loxahatchee River District also monitored water quality.

Since 1992, the Loxahatchee River Environmental Control District (Loxahatchee River District or LRD) has assumed responsibility for comprehensive monitoring in the watershed, monitoring 29 stations every other month. In recent years, additional monitoring stations have been added. **Figure 11** shows the applicable water quality sampling sites. In the early 1990s, the LRD, in cooperation with a technical advisory committee comprised of representatives of other monitoring efforts, organized the existing water quality data by collecting and screening all prior data. A common database was established, and the data presented in a format which could be indexed, composited and compared to Florida State values and standards. The resultant information was further organized by dividing the Loxahatchee watershed into 29 sample locations in four ecological segments (Marine, Estuarine, Wild and Scenic and Freshwater Tributaries). Five time-groupings covering 22 specific water quality parameters were developed. This summary was presented to the Loxahatchee River Management Coordinating Council in 1995 and is updated every six months.

Seven reaches or groups of stations have been monitored over the years within the "wild and scenic" portion of the Loxahatchee River. Additionally, six sampling sites are located in the freshwater tributaries flowing into the designated corridor. In general terms, the sampling results show that the water quality of the freshwater tributaries discharging to the "wild and scenic" corridor have remained fair for the period of record 1970–1993. The trend is for an overall decline in water quality in inflows over time. The "wild and scenic river" corridor also graded fair for the first portion of the monitoring period, then improved to good in the mid-1980s.

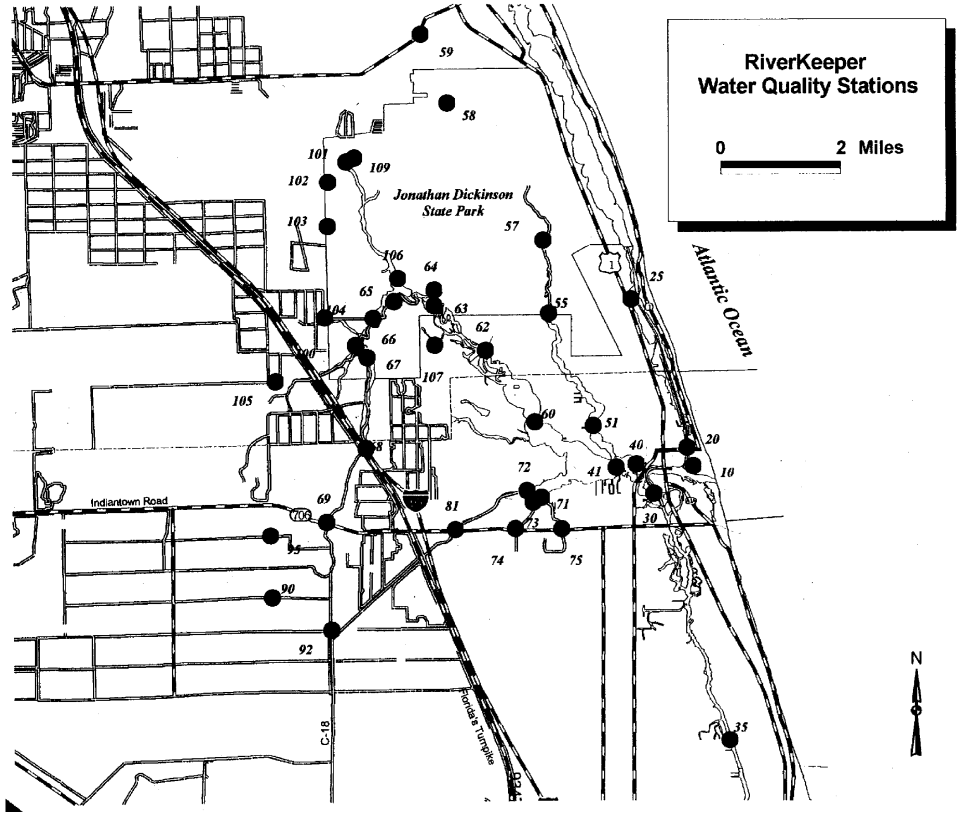


Figure 11. Water Quality Stations Sampled by the Loxahatchee River District

The major reason for the improvement and apparent inconsistency with the declining quality of input waters, is believed to be the increased flows to the Northwest Fork from the SFWMD C-18. The quality of water in the C-18, a Class I waterbody, has rated superior to the other freshwater inputs and has not shown significant degradation over time. Comparison of the long-term composite values for the Loxahatchee River Wild and Scenic River corridor with typical Florida stream water quality values (as documented by FDEP) yields the following conclusions:

- Clarity of the river water is near the statewide mean.
- Dissolved oxygen concentrations are low, ranking below about two-thirds of the other streams in Florida.
- Organic content of the waters is moderately better than statewide averages.
- Trophic status, predominantly nutrient concentration, is slightly better than values for other streams.
- Biological integrity of the "wild and scenic" reach is on the low side of the state mean, with six out of ten state streams displaying better results.
- Bacteria counts are substantially higher than the state standard, ranking ahead of only about 30 percent of other streams.

The Florida Water Quality Index for several thousand stream sampling sites averages 43. The statewide Water Quality (WQ) Index considers ratings of 45 or below as good, while ratings above 45 are considered fair. The 24-year average for the "wild and scenic" corridor is 48, however the index number for the period since 1985 has improved to 43. A station-to-station comparison of the river shows long-term water quality in each reach to display an index number near the mid-1940s with three exceptions. The reach above Indiantown Road, and the reach near the Trapper Nelson Interpretive Site both have index numbers at, or above, 50. These numbers are in the fair range, but more closely approximate poor. Flows entering from the C-18 have a composite index number of 40, which is very good.

Natural Systems

Major Plant Communities

The principal wetland plant communities in the vicinity of the river corridor are freshwater floodplain swamp and saltwater-tolerant mangrove swamps (**Figure 12**).

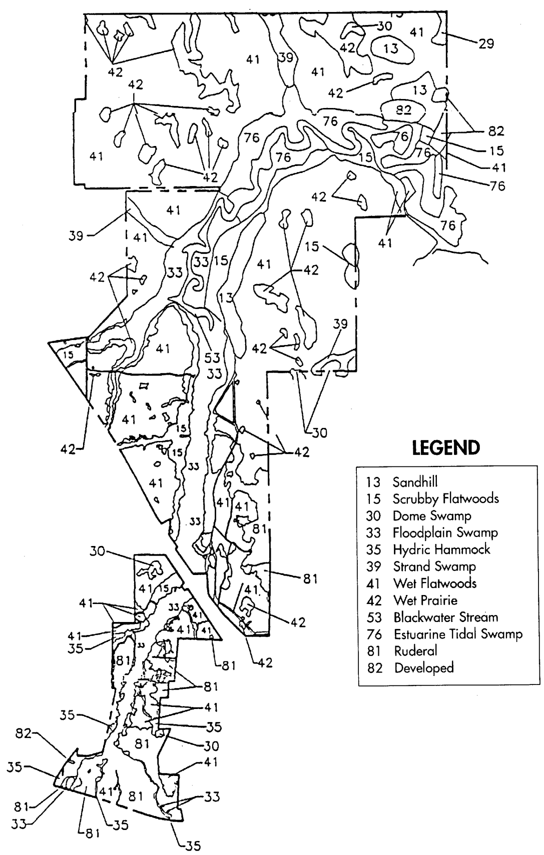


Figure 12. Wild and Scenic Corridor Plant Communities within Jonathan Dickinson State Park. (Source: FDEP and SFWMD 2000)

Low pine flatwoods and scrubby flatwood communities occupy the slightly higher elevations bordering the floodplain. Other vegetation communities found in the area include sandhill, cypress dome swamp, hydric hammock, cypress strand swamp and wet prairie. The hardwood/cypress swamp community flanks the river and its tributaries upstream from the Trapper Nelson Interpretive Site, and is the dominant community for approximately one mile downstream of the site. This community is composed of bald cypress, southern red maple, cabbage palm, pop ash, pond apple, laurel oak and water hickory. Shrubby species mixed among the taller vegetation include cocoplum, wild coffee, myrsine and buttonbush. Vines, ferns, bromeliads and orchids also are characteristic of this community.

The mangrove community lines the Northwest Fork from approximately one mile downstream of the Trapper Nelson Interpretive Site. Red mangroves front the river where they are most fully exposed to tidal flows. Some dead cypress trees tower above the red mangroves for approximately three quarters of a mile downstream from this point, evidence of the extent of freshwater vegetation that existed before changes in the upstream movement of saltwater. White mangroves are further back from the river channel but near enough to be inundated at high tide.

The low pine flatwood community is dominated by widely scattered South Florida slash pine. The slightly elevated, level sandy areas in which this plant community is found lack the soils and drainage conditions necessary to support the type of dense understory found in the floodplain. Vegetation is typically shrubby in nature, and includes the saw palmetto, gallberry and fetterbush. Ground cover includes wiregrass, broom sedge and various herbaceous species. Scrubby flatwoods typically occupy the elevations above the pine flatwoods and alongside the floodplain. The sandy soil is usually several feet deep and drains rapidly even under extremely wet conditions. The dominant species is the South Florida slash pine, as in the pine flatwoods, but the understory is characterized by scrub oak and other scrub vegetation.

The principal problem affecting the river's plant communities is the gradual reduction in the number and geographic extent of healthy floodplain swamp and bald cypress and their replacement by mangroves. Virtually all of the cypress in the lowermost area of the “wild and scenic river” segment are now dead, or are stressed and not reproducing. Approximately one mile upstream of Kitching Creek, the number of live trees increases with increasing distance up the river. An analysis conducted by the U.S. Geological Survey between 1979 and 1982 documented the extent of environmental stress in the cypress trees along the Loxahatchee River corridor (McPherson, unpublished). The study examined core samples to identify changes in tree ring width and quality. The results of the study indicated that although the trees sampled had experienced stress at periodic intervals over their life histories, the proportion of stressed trees in the downstream section (below river mile 9.0) increased from 30 percent in 1940 to 80 percent in 1982. Stressed trees above river mile 9.0 decreased from 11 percent to 3 percent during that period. Further, the incidence of growth stress was highly correlated with high salinities in surface water and soils (Duever and McCollom 1982).

Based studies conducted as part of the Wild and Scenic River Management Plan (SFWMD, 2000) it was concluded that the decline of cypress in the river was due to the upstream movement of saltwater. Exposure to saline waters may have either acute or chronic toxic effects. Occasional inundation by slightly saline surface water probably does not result in serious or long-term impacts. Periodic exposure to high salinity water or frequent exposure to lower salinities, however, may increase the salinity of the floodplain's peat soils. The principal causes of saltwater intrusion were identified and attempts are underway to establish correlations between degree and duration of salinity stress and effects on tree reproduction growth and survival tree growth. Four contributing factors were identified as causes of increased upstream salinity exposure as follows: (1) permanent opening of the Jupiter Inlet in 1947, (2) Construction of C-18 Canal in 1957-58, resulting in insufficient dry season flows to the Northwest Fork; (3) dredging in the river's estuary, the ICW and Jupiter Inlet; and (4) the drawdown of ground water levels by wells in the Jupiter-Tequesta area. Each of these factors must be addressed if deterioration of the river's cypress communities is to be reversed (SFWMD, 2000)

Wetlands

The Loxahatchee River Basin Wetland Planning Project (Treasure Coast Regional Planning Council, 1999) was initiated in 1994 to identify wetlands in the Loxahatchee River Basin and provide information about the functions and values of these wetlands. The major wetland systems in the Loxahatchee River basin are listed in **Table 9.** Interpretation of the infrared aerial photographs resulted in the identification of areas of high, medium and low quality wetlands. Seventy-nine percent of the wetlands in the project area are located in areas of high quality wetlands, 13 percent in areas of medium quality wetlands and 8 percent in areas of low quality wetlands. The largest area of high quality wetlands is the Loxahatchee Slough. The second largest area of high quality wetlands is Pal-Mar. Other locations identified as areas of high quality wetlands include Corbett Wildlife Management Area, the Cypress Creek Area, the Loxahatchee River Save Our Rivers property north of Indiantown Road, large preserve areas on the North Palm Beach County General Aviation Airport and PGA National and a portion of Vavrus Ranch.

The largest areas of medium quality wetlands occur in Unit 11 of the Acreage, the Sandhill Crane Addition to the Loxahatchee Slough Natural Area, portions of the Vavrus Ranch and Loxahatchee River Save Our Rivers property south of Indiantown Road. Other locations identified as areas of medium quality wetlands are the preserve areas on sites that have been developed during the last 20 years. These include Old Marsh Golf Club, Palm Beach Park of Commerce, and the smaller preserve areas on PGA National and the North Palm Beach County General Aviation Airport. Two additional sites, which have since been developed, were areas of medium quality wetlands -- Golf Digest (Mirasol) and Country Lakes of Jupiter.

The main areas of low quality wetlands include Jupiter Farms, Palm Beach Country Estates, Caloosa and the Acreage south of Mecca Farms. A portion near the center of Vavrus Ranch is also identified as an area of low quality wetlands.

Twenty-four percent of the wetlands in the watershed are freshwater marsh and wet prairie, hardwood swamp and cypress swamp. The main concentrations of freshwater marsh and wet prairie are located in and near the Loxahatchee Slough, Corbett Wildlife Management Area and Pal-Mar. The largest concentration of hardwood swamp occurs along the Loxahatchee River. The main concentrations of cypress swamps occur in and just east of the Cypress Creek area north of Indiantown Road, and in and adjacent to the Loxahatchee Slough, especially near the Beeline Highway. A large stand of cypress also occurs in Corbett Wildlife Management Area just south of Pratt & Whitney (Treasure Coast Regional Planning Council, 1999).

Table 9. Major Wetland Systems in the Loxahatchee River Watershed

Wetland System	Area	County	Location	Ecosystems	Hydrology
Atlantic Coastal Ridge	12,700 ac.	Eastern Martin	Between I-95 and U.S. Hwy 1	Extensive upland and wetland systems, including wet flatwoods, marshes, forested sloughs and coastal scrub	Includes the headwaters of the South Fork of the St. Lucie River, North Fork of the Loxahatchee River and Kitching Creek
Cypress Creek	4.5 sq. mi.	Martin & Palm Beach	North of Indiantown Rd., west of the Northwest Fork	Forested and interspersed with marshes, cypress swamps and wet prairies	Forms the headwaters of Cypress Creek
Jonathan Dickinson State Park	11, 500 ac.	S.E. Martin	The Park surrounds Kitching Creek and portions of Cypress Creek, the Northwest Fork and the North Fork of the Loxahatchee River	Extensive wet pine flatwoods, marshes, wet prairies and forested swamps	Surrounds Kitching Creek and portions of Cypress Creek, the Northwest Fork and North Fork of the Loxahatchee River
J.W. Corbett Wildlife Management Area	57, 000 ac.	Northern Palm Beach	Adjacent to DuPuis Reserve	Wet flatwoods, mesic flatwoods, wet prairies, marshes, cypress swamps and remnants of the Everglades	The Hungryland Slough begins in Corbett and flows east until it meets the Loxahatchee Slough
Hungryland Slough	3,000 ac[1]	Palm Beach	Northwestern portion of the Loxahatchee Slough Natural Area	Pine flatwoods, wet flatwoods, cypress swamps, depression marshes and wet prairies	A remnant slough; formerly flowed from the area near Corbett WMA to merge with the northern portion of the Loxahatchee Slough; drained by the west leg of the C-18; drainage is to the east toward the Loxahatchee Slough
Loxahatchee River Preserve Area	1, 926 ac.	Southern Martin & Northern Palm Beach	Adjacent to JDSP and Palm Beach County's Riverbend Park	River floodplain	Surrounds the Loxahatchee River and includes a portion of the historic floodplain of the Northwest Fork
Loxahatchee Slough	>13, 000 ac.	Palm Beach	West of the Turnpike and north of SR 710	Wet flatwoods, marshes, cypress swamps, wet prairies and hydric hammock	The Loxahatchee Slough flows north from the West Palm Beach Water Catchment Area toward the Northwest Fork of the Loxahatchee River; Drained by the east leg of the C-18
Pal-Mar	37, 000 ac.	Southern Martin & Northern Palm Beach	East of Beeline Hwy., north of Indiantown Rd. and west of SR 711	Pine flatwoods, marshes and wet prairies	Hydrology is nearly unaltered, ditches and canals are present but have not caused significant impact to the historic flow of water
South Fork of the St. Lucie River	184 ac.	NW Martin	Adjacent to the Atlantic Coastal Ridge	Riverine system	Surrounds the lower reaches of the river
West Palm Beach Water Catchment Area	19.3 sq. mi.	Palm Beach	Impounded portion of the Loxahatchee Slough located south of SR 710	Pine flatwoods, hydric pine flatwoods, hardwood hammocks, marsh and cypress heads and cypress-shrub	Limited connection to the Loxahatchee Slough via two culverts under the Beeline Highway; Historic headwaters of the Northwest Fork of the Loxahatchee River

Source: Treasure Coast Regional Planning Council 1999, Martin County Planning Dept. 2000; [1] PBC ERM Staff

Uplands

According to the 1984 National Wetlands Inventory, 61.3 percent of the Loxahatchee River watershed is uplands. Upland communities present in the Loxahatchee River watershed are sandhill, pine flatwoods, hydric pine flatwoods, sand pine scrub, xeric oak scrub, beach and dune systems (Treasure Coast Regional Planning Council, 1999). The watershed contains some of the last remaining coastal sand pine scrub communities on Florida's southeast coast (FDEP, 1998).

Estuary

The estuary is centrally located within the Loxahatchee River watershed **(Figure 2)** and receives freshwater from three major tributaries of the Loxahatchee River and seawater from the Jupiter Inlet. The mixing of seawater and freshwater creates the brackish water characteristic of the estuary. The central embayment is shallow with an average depth of four feet and the area is 0.6 square miles (FDEP, 1998; Antonini et al., 1998).

Natural communities in the estuary are seagrass beds, tidal flats and oyster beds. The tidal and freshwater flows determine bottom sediment characteristics and sustain several distinct biological communities. Seagrass beds and oyster bars grow where suitable undisturbed bottom sediment occurs and where tides maintain adequate salinity and flow conditions (FDEP, 1998). Seagrass covers approximately 5 percent of the water areas. It is found fringing the shoreline; as extensive beds southwest of the sandbar and in shoal water at the mouth of the North Fork, and as patches between Dolphin and Marlin canals and between the mangrove islands and the Alternate A1A Bridge. (Antonini et al., 1998)

Plants and Animals

The combination of climate, vegetation and water bodies in the Loxahatchee River area has resulted in a high diversity of animal species. In 1965, two hundred sixty-seven species, consisting of 169 genera and 78 families were observed in and along the river and its estuary. The area surrounding the Northwest Fork is inhabited by numerous vertebrate species identified as endangered, threatened or of special concern by the Florida Fish and Wildlife Conservation Commission (FWC), or listed as threatened or endangered by the United States Fish and Wildlife Service (USFWS). State and federally listed animals in the watershed are shown in **Table 10** and listed plants are shown in **Table 11.**

In addition, the entire Loxahatchee River has been designated by USFWS as a critical habitat for the West Indian manatee. Invertebrate and vertebrate aquatic animals are numerous in the marshes, lakes and streams in the river area. Freshwater fish include largemouth bass, speckled perch, bluegill, shellcracker, redbreast, warmouth, bowfin, gar, channel catfish and many species of minnows. The manatee, an endangered aquatic mammal, frequents the Loxahatchee River estuary. Numerous turtles also live in and around the river. Saltwater fish include snook, tarpon, mullet, bluefish, jack, sheepshead, drum, sand perch, grouper, snapper and flounder. Mammals and birds are frequently encountered along the riverbank. The more commonly seen species include raccoon, opossum, whitetail deer, osprey, barred owl, egrets, herons and ibis.

Additional species, although not identified on the official lists compiled by the State of Florida, may be identified as being either endangered, threatened or of special concern by the Florida Committee on Rare and Endangered Plants and Animals. The threatened osprey often nests in dead cypress trees in the lower Northwest Fork. The great egret, the black-crowned night heron and the yellow-crowned night heron, classified as Species of Special Concern, are also found in the Loxahatchee River area.

The Loxahatchee National Wild and Scenic River and JDSP contain 52 federal and state species that are endangered, threatened, or of special concern (23 animals and 29 plants). Those species having a federal designation found within this area are: the alligator, indigo snake, scrub jay, bald eagle, wood stork, snail kite, manatee, four-petal paw paw, perforate lichen and Small's milkwort (FDEP, 1998).

Table 10. Threatened and Endangered Animals and Species of Special Concern in the Loxahatchee River Watershed

Scientific Name	Common Name	FCREPA[1]	FWC[2]	FDA[3]	USFWS[4]
MAMMALS					
Blarina carolinensis shermani	Sherman's short-tailed shrew	SSC	SSC		
Eumops glaucinus	Florida mastiff bat		E		E
Felis concolor coryi	Florida panther		E		E
Peromyscus floridanus	Florida mouse	T	SSC		
Sciurus niger shermanii	Sherman's fox squirrel	T	SSC		
Trichechus manatus latirostris	West Indian manatee	T	E		E
BIRDS					
Ajaia ajaja	Roseate spoonbill	R	SSC		
Aphelocoma coerulescens	Florida scrub jay	T	T		T
Aramus guarauna	Limpkin	SSC	SSC		
Dendroica kirtlandii	Kirtland's warbler	E	E		E
Egretta caerulea	Little blue heron	SSC	SSC		
Egretta thula	Snowy egret	SSC	SSC		
Egretta tricolor	Tricolored heron	SSC	SSC		
Eudocimus albus	White ibis	SSC	SSC		
Falco pergrinus tundrius	Arctic peregrine falcon	E	E		
Falco sparverius paulus	Southeastern American kestrel	T	T		
Grus canadensis pratensis	Florida sandhill crane	T	T		
Haliaeetus leucocephalus	Bald eagle	T	T		T
Mycteria americana	Wood stork	E	E		E
Pelecanus occidentalis	Brown pelican		SSC		
Picoides borealis	Red-cockaded woodpecker	E	T		E
Polyborus plancus audubonii	Crested caracara		T		T
Rostrhamus sociabilis	Snail kite	E	E		E
Speotyto cunicularia floridana	Florida burrowing owl	SSC	SSC		
Sterna antillarum	Least tern	T	T		
FISH					
Centropornus undecimalis	Common snook		SSC		
AMPHIBIANS					
Rana capito aesopus	Gopher Frog	T	SSC		
REPTILES					
Alligator mississippiensis	American alligator	SSC	SSC		T(S/A)
Drymarchon corais couperi	Eastern indigo snake	SSC	T		T
Gopherus polyphemus	Gopher tortoise	T	SSC		
Pituophis melanoleucus	Florida pine snake		SSC		

Treasure Coast Regional Planning Council, 1999. Jonathan Dickinson State Park Unit Management Plan -State of Florida Department of Environmental Protection, February 2000. [1] Florida Committee on Rare and Endangered Plants and Animals [2] Florida Fish and Wildlife Conservation Commission [3] Florida Department of Agriculture and Consumer Services [4] United States Fish and Wildlife Service. E=Endangered, R=Rare, T=Threatened, T(S/A)=Threatened/Similarity of Appearance, SSC=Species of Special Concern.

Table 11. Threatened and Endangered Wetland Plant Species that Occur in the Project Area

Scientific Name	Common Name	FCREPA[1]	FDA[3]	USFWS[4]
Acrostichum danaeifolium	Giant leather fern		C	
Actinostachys pennula	Fern ray/Tropical curly-grass fern		E	
Asclepias curtissii	Curtiss' milkweed		E	
Asimina tetramera	Four-petal pawpaw		E	E
Azolla caroliniana	Mosquito fern		T	
Bletia purpurea	Pine pink orchid		T	
Calopogon barbatus	Bearded grass pink		T	
Calopogon multiflorus	Many-flowered grass pink		E	
Campyloneurum latum	Strap fern		E	
Campyloneurum phyllitidus	Long strap fern		E	
Chamaesyce cumulicola	Sand dune spurge		E	
Chrysophyllum oliviforme	Satinleaf		E	
Cladonia perforata	Perforate reindeer lichen		E	E
Conradina grandiflora	Large-flowered rosemary		E	
Dennstaedtia bipinnata	Cuplet fern	E	E	
Drosera intermedia	Water sundew		T	
Encyclia cochleata	Clamshell orchid		E	
Encyclia tampensis	Butterfly orchid		C	
Epidendrum rigidum	Rigid epidendrum		E	
Ernodea littoralis	Beach creeper		T	
Eulophia alta	Wild coco		T	
Habenaria nivea	Snowy orchid		T	
Halophila johnsonii	Johnson's seagrss			T
Hexalectris spicata	Crested coralroot		E	
Ionopsis utricularioides	Delicate ionopsis		E	
Lechea cernua	Nodding pinweed		T	
Lechea divaricata	Pine pinweed		E	
Lilium catesbaei	Catesby's lily		T	
Lycopodium cernuum	Nodding club moss		C	
Nemastylis floridana	Celestial lilt	T	E	
Nephrolepis biserrata	Giant sword fern		T	
Ophioglossum palmatum	Hand adder's tongue fern	E	E	
Osmunda cinnamomea	Cinnamon fern		C	
Osmunda regalis	Royal fern		C	
Pecluma ptilodon	Swamp plume polypody		E	
Peperomia humilis	Low peperomia		E	
Phlebodium aureum	Polyplody fern		T	
Pinguicula caerulea	Blue-flowered butterwort		T	
Pogonia ophioglossoides	Rose pogonia		T	
Polygala smallii	Small's milkwort		E	E
Psilotum nudum	Whisk fern		T	
Pteroglossaspis ecristata	Non-crested coco		T	
Salvinia rotundifolia	Water spangles		T	
Spiranthes laciniata	Lace-lip ladies' tresses		T	
Spiranthes longilabris	Long-lip ladies' tresses		T	
Spiranthes vernalis	Ladies' tresses		T	
Stenorrhynchos lanceolata	Leafless red beak orchid		T	
Thelypteris interrupta	Aspidium fern		T	
Thelypteris kunthii	Aspidium fern		T	
Thelypteris palustris	Aspidium fern		T	
Thelypteris serrata	Dentate lattice vein fern		E	
Tillandsia balbisiana	Inflated wild pine		T	
Tillandsia fasciculata	Common wild pine		E	
Tillandsia flexuosa	Twisted air plant	T	E	
Tillandsia utriculata	Giant wild pine		E	
Tillandsia valenzuelana	Soft-leaved wild pine		T	
Tillandsia variabilis	Soft-leaved wild pine		T	
Tolumnia bahamensis	Dancing lady orchid		E	

Treasure Coast Regional Planning Council, 1999. Jonathan Dickinson State Park Unit Management Plan -State of Florida Department of Environmental Protection, February 2000. [1] Florida Committee on Rare and Endangered Plants and Animals [2] Florida Fish and Wildlife Conservation Commission [3] Florida Department of Agriculture and Consumer Services [4] United States Fish and Wildlife Service. E=Endangered, R=Rare, T=Threatened, T(S/A)=Threatened/Similarity of Appearance, SSC=Species of Special Concern.

Navigation and Recreation

Use of the Loxahatchee River and Estuary by motorized craft is essentially limited by channel depth, width and vertical clearance of bridges. Boats much larger than 25 to 30 feet are limited to the lower portions of the river by both lack of depth and vertical clearance (Law, 1991b). The estuary central embayment is a shallow water region. Over 50 percent of this area is less than two feet deep. The main river channel is the only improved access channel in the central embayment (Antonini et al., 1998).

The reaches of the Loxahatchee included in the "wild and scenic" corridor have relatively limited public access points to the river (**Figure 13**). Existing access and major facilities that support public use are clustered at each end of the 7.5 mile "wild and scenic" segment, concentrating public use in these areas. Most existing river related recreational uses and major

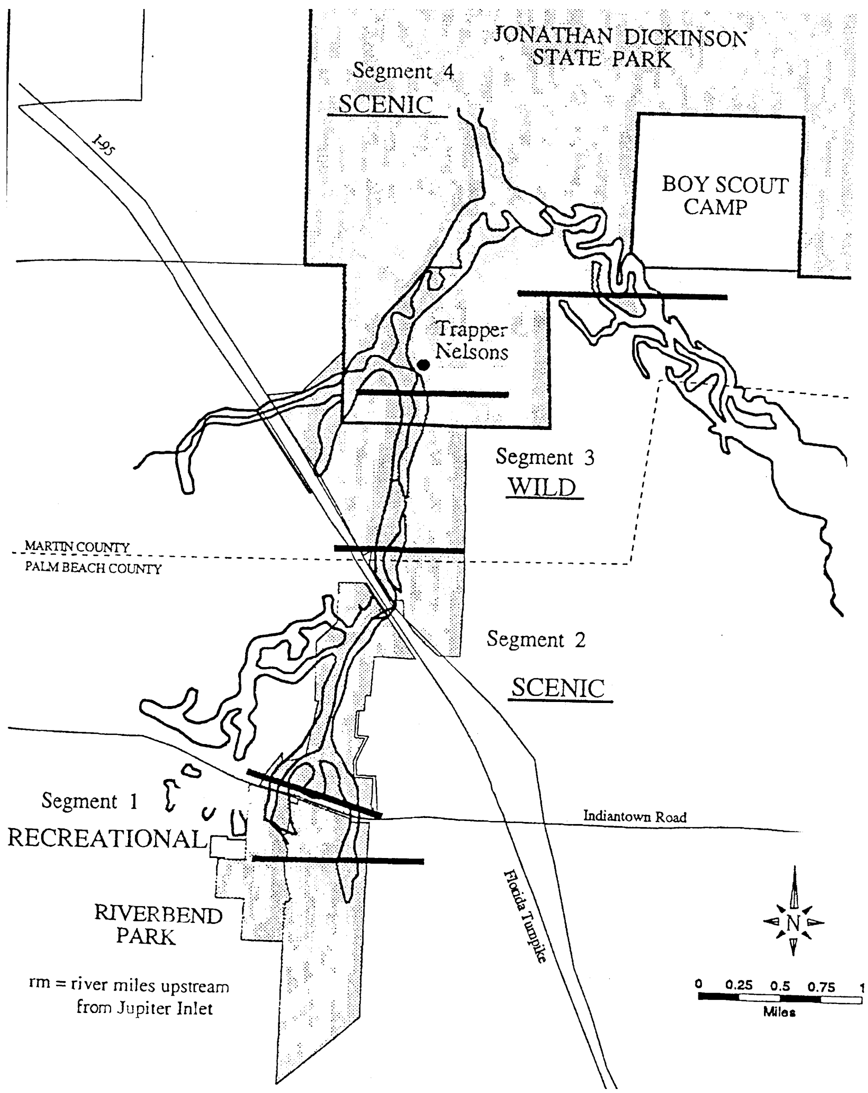


Figure 13. Loxahatchee Wild and Scenic River Corridor Classifications.

facilities occur within JDSP, but in the future other major facilities will be provided and managed by Palm Beach County at Riverbend County Park. Riverbend County Park, which includes the SFWMD's Reese and Gildan tracts, and JDSP are the two primary public access areas on the River. Riverbend County Park, located between Indiantown Road and the C-18, comprises more than 600 acres and encompasses the half mile “recreational” segment of the river corridor.

Public access to the River at the downstream end of the “wild and scenic” corridor is available at two points. Both are JDSP boat docks. The first is the primary launching and take-out point for canoeists who rent boats from the park concessionaire. It is also the staging area for river cruises on the 44-foot "Loxahatchee Queen II", operated by the concessionaire. Restrooms, trails, cabins and picnicking facilities are nearby. The other facility is located 0.5 miles downriver and consists of a concrete boat dock and ramp. It is adjacent to a developed campground within JDSP. This site is used primarily by park visitors who bring their own boats and canoes, but is also used as the take-out point by canoeists completing the trip downstream from Riverbend County Park. Several secondary access, or resting, points exist in the river corridor area, but these are relatively insignificant as contributing sources of use pressure.

The Loxahatchee River's natural features and its proximity to the urban areas of Southeast Florida make it exceptionally well suited to provide outdoor recreation. Historically, canoeing has been the main recreational use of the river and its surrounding area, but other activities include kayaking, fishing, nature study, wildlife observation and motor boating. Motor boating is effectively restricted to the portion of the river downstream from the Trapper Nelson Interpretive Site because of the narrow channel, numerous obstructions and shallow depth of the upper river. Virtually all public recreational use of the upper river involves paddling, either as a recreational activity or as a means of gaining access to the river area to enjoy other activities.

An important function of the river management program is to determine and monitor the quantity and mixture of recreation and other public use, which can utilize the river without adverse impacts on its resource values. The recreation "carrying capacity" of rivers has received the attention of river managers for more than a decade, but there is little consensus as to the most appropriate means for estimating carrying capacity. This is because carrying capacity is a dynamic concept and a number of factors exist, including management objectives, the physical and biological nature of the resource, and the preferences and tolerances of users, which must be considered together in determining a river's carrying capacity (FDEP and SFWMD 2000)

WATER RESOURCE ISSUES -- PROBLEMS IDENTIFIED

The following information was taken from the *Loxahatchee River Watershed Action Plan* (FDEP, 1998).

Surface Water Resources

Altered Hydroperiod. In response to flooding, drainage ditches and canals have been built to drain developed areas. Canals divert water and affect the historical flow patterns to natural wetland systems. Barriers have been built in many areas that interfere with the historical movement of water in this region. These impediments, including canals and roads, intensify flooding in some areas. This network of canals and barriers has reduced water storage in natural areas, caused flooding in other areas and degraded water quality in surface waters.

Water Quality. Most of the upper watershed has not experienced major water quality problems. Some problems have been noted in the lower watershed, including decreasing DO in the "wild and scenic" Northwest Fork of the Loxahatchee River, and nutrient loading in the estuary.

Lack of Surface Water Quality Data. There is a lack of historical surface water quality data in some parts of the watershed, including the North Fork, Cypress Creek and other tributaries of the Loxahatchee River Watershed. Due to chronic water supply issues, the potential for saltwater intrusion and potential impacts to nearby wetlands and the Loxahatchee River, local utilities in this area already make extensive use of the Floridan Aquifer, reuse of reclaimed water and water conservation practices to help meet increasing water demands.

Storm Water Runoff. Storm water runoff introduces contaminants from developed areas into surface water. Contaminants include pesticides, nutrients, oils and grease and suspended solids. These contaminants can reduce DO, which can cause fish kills. The watershed has several older neighborhoods that were developed without adequate storm water systems. This can cause flooding during heavy rainfall.

Saltwater Intrusion. Reduced flow in the Northwest Fork of the Loxahatchee River has allowed saltwater to migrate upriver causing the introduction of mangroves into areas once dominated by freshwater floodplain swamp.

Scouring/Siltation. During heavy rain events, tremendous flows cause scouring in residential and agricultural canals, which increases sediment loading into surface waters. This phenomenon causes sedimentation in the navigable channels and has an adverse effect on the aquatic plants and animals.

Ground Water Resources

Wellfield Pumping. Over pumping ground water has the potential to cause wetland drawdown impacts and saltwater intrusion into the freshwater aquifer. Under SFWMD rules utilities are not allowed to over pump the ground water within the Loxahatchee watershed.

Ground Water Contamination. With the exception of the West Palm Beach Catchment Area, the majority of drinking water within the watershed is derived from ground water. The most common source of ground water contamination is leaking fuel storage tanks. Other contamination sources include dry cleaners, pesticide storage areas and other operations that handle hazardous materials. With the exception of Sub-basin 6, there are known ground water contaminated sites in all of the other subbasins. Further details pertaining to these contaminated sites can be found within the FDEP's 1998 Watershed Action Plan (FDEP, 1998).

Wastewater Treatment. Nutrients leaching from septic tank drainage fields may seep into ground water, which ultimately feeds surface waters. In some areas this can have a negative impact on water quality. Human sewage waste entering surface water poses a health threat to swimmers and other recreational users.

Habitat Management

Sustainable Usage - Recreation and Fisheries. With more and more people moving into the area, there is increased pressure on natural resources and more competition for limited recreational resources. Increased fishing puts more pressure on fish stocks. Boat propellers in shallow areas can damage seagrass beds. Fishing may not be compatible with competing activities, such as water skiing and jet skis. The "wild and scenic" Northwest Fork of the Loxahatchee River is a popular destination for canoe and kayak enthusiasts. Increased boat traffic has caused concern that the river's carrying capacity will be exceeded.

Exotic Pest Plants. Exotic pest plant species have been introduced into Florida for decorative landscaping, agriculture and to dry up wetlands for development. The ability of these exotic species to reproduce rapidly, due to a lack of predatory pressure, allows them to spread quickly into natural ecosystems. The exotic pest plants of most concern in the watershed are Old World climbing fern *(Lygodium microphyllum)*, melaleuca *(Melaleuca quinquenervia)*, Brazilian pepper *(Schinus terebinthefolius)*, Australian pine *(Casuarina* spp.*)* and downy rose-myrtle *(Rhodomyrtus tomentosa)*. Several other exotic aquatic plants occur in natural waterways and canals, impede navigation and cause water quality and habitat problems.

Exotic Animals. Exotic animals also upset the natural balance of ecosystems. Some examples of exotic animals in the Loxahatchee River watershed include feral hogs, armadillos and the black acara.

Fire Management. Fire-dependent plant communities, including pine flatwoods and sand pine scrub, are found throughout the watershed. Due to the proximity of residential neighborhoods to these natural areas, naturally occurring fires from lightning strikes must be controlled to protect property. Land managers implement prescribed burn plans to provide the necessary fire cycle to renew these habitats. Prescribed fire management plans identify optimum wind conditions for conducting controlled bums, so that the smoke will not impact local residents. As more residential homes are constructed adjacent to natural areas, smoke management will become more difficult. The absence of fire management on privately owned land with fire-dependent plant communities presents problems for the implementation of necessary land management practices on publicly-owned land.

Habitat Fragmentation and Habitat Loss. Altered hydroperiod, development, exotic plant invasions and lack of land management have contributed to wildlife habitat loss and fragmentation.

Off-Road Vehicle Damage to Habitat. Users of off-road vehicles are accessing privately owned, undeveloped parcels. The use of these vehicles on undeveloped land damages the native plant understory. Exotic pest plants often invade these disturbed areas.

Solid Waste Dumping. Dumpers use isolated roads in low density residential developments to avoid paying tipping fees at the landfill or costly hazardous waste disposal fees. Hazardous constituents from waste piles can leach into the environment, and also pose physical hazards to wildlife and humans. Waste tire piles, for example, provide breeding habitat for mosquitoes. The cost of cleaning up illegally dumped waste falls on the property owner if the dumper is not identified and forced to pay.

Urban Sprawl: Sprawl is defined as housing areas that are isolated or poorly connected to existing neighborhoods. The impacts of urban sprawl on natural resources can be direct (e.g., loss of habitat) or indirect (e.g., alteration of the water table in nearby wetlands).

Loxahatchee River Watershed Problem Matrix

The following matrix (**Table 12**) indicates which problems occur in the subbasins shown in **Figure 5**. Some problems are found throughout the watershed including altered hydroperiod and exotic pest plants. Other problems are isolated and affect only one or two subbasins, such as beach erosion and off road vehicle damage. Part II of the Watershed Action Plan (FDEP, 1998) proposes projects to address many of the problems identified in the watershed subbasins.

Table 12. Problems Identified Within the Various Subbasins of the Loxahatchee River Watershed

Current Problems	Subbasin 1 Jonathan Dickinson/ Hobe Sound	Subbasin 2 Coastal	Subbasin 3 Estuary	Subbasin 4 C-18/ Corbett	Subbasin 5 Cypress/ Pal-Mar	Subbasin 6 Citrus	Subbasin 7 Wild & Scenic
Altered Hydroperiod	X	X	X	X	X	X	X
Water Quality			X				X
Lack of Water Quality Data	X			X	X	X	X
Storm Water Runoff	X	X	X			X	X
Saltwater Intrusion							X
Scouring/Siltation			X		X		X
Wellfield Pumping	X						
Ground Water Contamination	X	X	X	X	X		X
Wastewater Treatment	X	X	X				X
Sustainable Usage		X	X				X
Exotic Pest Plants	X	X	X	X	X	X	X
Exotic Animals	X			X	X	X	
Fire Management	X	X		X	X	X	
Habitat Fragmentation	X	X	X	X	X	X	X
Off Road Vehicle Impacts				X	X		
Solid Waste Dumping			X	X	X		X
Urban Sprawl	X			X	X		X